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PRELIMINARY EVALUATION OF MERCURY-REDSTONE LAUNCH MR-BD (U)

By

W. G. Clarke apr 19, 1961 refs

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MARSHALL SPACE FLIGHT CENTER

MTP-AERO-61-36

PRELIMINARY EVALUATION OF MERCURY-REDSTONE LAUNCH MR-BD (U)

By

W. G. Clarke

(C) ABSTRACT

Mercury-Redstone MR-BD was launched from the Atlantic Missile Range on March 24, 1961 at 1230 EST. The primary mission of the test flight was verification of changes incorporated in the Mercury-Redstone booster after the MR-2 flight.

All missions of the test were achieved. Preliminary analysis of the flight data indicated only very slight deviations from expected performance. All systems functioned properly and no problem areas were revealed.

The filter network incorporated in the control system to reduce feedback in the second bending mode frequencies was successful. The maximum vane deflections due to second mode feedback were reduced by a factor of two from those recorded for the MR-2 flight. The second bending mode frequencies again appeared in the angular velocity measurements, but the amplitude was only half that of MR-2. This indicates that the control filter, the damping compound, and stiffness in the adapter section were effective in reducing the amplitude of the oscillations.

The automatic abort system, open loop for this flight, functioned as expected. All measured data from the sensors showed levels well below the abort limits.

Cutoff was given by the integrating gyro at the proper velocity. This gives further evidence that the fix applied to the gyro after flight test MR-1A has corrected the noted deficiency.

Impact occurred at a range of 276.7 nm, 1.5 nm (2.7 km) over and 2.6 nm (4.9 km) to the right of the target.

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April 19, 1961 Report No. MTP-AERO-61-36

PRELIMINARY EVALUATION OF MERCURY-REDSTONE LAUNCH MR-BD (U)

By

W. G. Clarke

FLIGHT EVALUATION BRANCH
AEROBALLISTICS DIVISION

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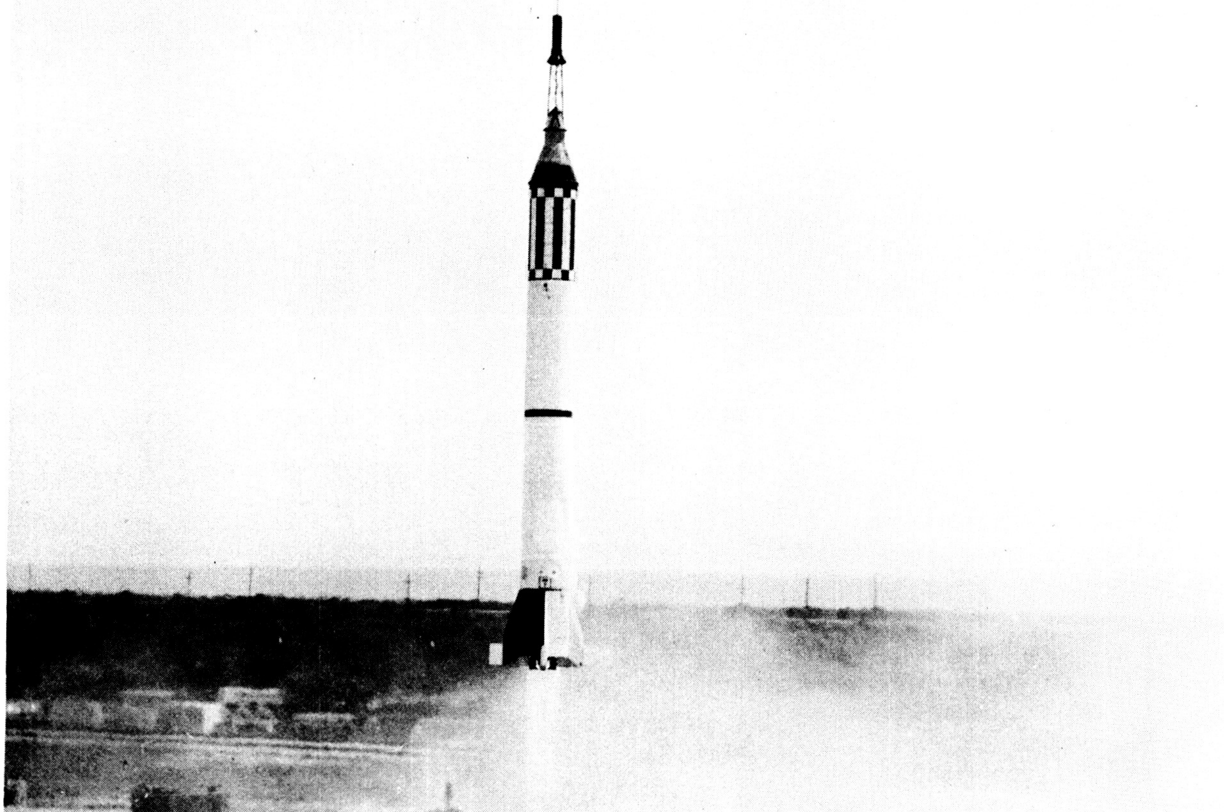

(U) INTRODUCTION

This preliminary evaluation report of the Mercury-Redstone MR-BD flight is published three weeks after launch.

This report which constitutes the coordinated results of the evaluation efforts from various divisions of the MSFC is prepared for the Space Task Group in accordance with established requirements. It represents the official MSFC position as to nature and explanation of all essential flight occurrences.

This preliminary report will not be followed by any additional or final reports of a similar type unless continued analysis and/or new evidence should prove the conclusions presented here partly or wholly wrong.

MR-BD, a combination of booster no. 5 and a dummy capsule with an inert escape tower, was launched at 1230 EST on March 24, 1961 from complex 56, Pad 5 of the Atlantic Missile Range.

Special acknowledgment for contributions to this report is given to M-S&M-PV, M-S&M-SD, M-G&C-N, and M-AERO-F.

1. (C) MISSIONS AND FEATURES

Missions assigned to MR-BD were as follows:

<u>Primary Missions</u>

a. Confirmation of control system modification which was incorporated to overcome the vane feedback - second bending mode problem including a programmed maneuver - achieved.

b. Determine the compatibility of redesignated flight sequence time - achieved.

c. Determine the effectiveness of structural coating and stiffening on forward portion of the aft section - achieved.

<u>Secondary Missions</u>

a. Further confirm changes incorporated as a result of tests MR-1, MR-1A, and MR-2 - achieved.

b. Determine effect of eliminating roll rate abort switch - achieved.

c. Record performance of thrust controller and peroxide zero value - achieved.

d. Determine performance of booster automatic abort system - achieved.

e. Further verify vehicle flight performance - achieved.

f. Further verify performance of the booster ground support equipment - achieved.

The features pertaining to Mercury-Redstone vehicle MR-BD are as follows:

a. The capsule, built by McDonnell Aircraft Corporation, was a simulated capsule corresponding to the normal flight capsule in dimensions and aerodynamic configuration and ballasted to provide a normal weight and balance effect. The capsule was attached in the normal manner except that no separation was to occur. Hence, all pyrotechnic devices and internal capsule instrumentation were omitted. The capsule contained one Sofar bomb for checkout of the BOA Missile Impact System.

b. The capsule was boosted into a ballistic trajectory by a modified Redstone booster with an LEV-3 antopilot system. The Redstone booster was elongated to allow for extra fuel tankage and had a capsule adapter. The booster had the following systems onboard: one telemetry link, Dovap, Azusa, destruct system and an abort sensing and implementation system (flown open loop).

c. The vehicle was 83.01 feet in length (including capsule) and had a total weight of 66,156 pounds at liftoff. The usual Redstone propellants were used (75 percent Ethyl alcohol - 25 percent water mixture, and liquid oxygen).

2. (U) LAUNCH

Mercury-Redstone MR-BD was scheduled for launch at 1300 EST on March 24, 1961. The launch time was advanced to 1230 EST at the request of the Atlantic Missile Range.

No holds were required during the countdown; however, some trouble with the LOX topping device was experienced. The automatic tanking computer kept topping LOX, resulting in an overflow. This situation was probably caused by some of the LOX sloshing into the high level pressure sensing line, giving false sensing indications to the computer. A 16-20 knot wind was partially responsible for the excessive LOX sloshing. By lowering the bias in the topping circuit, the LOX level was decreased sufficiently to allow normal LOX topping operations. A new ΔP (pressure which determines LOX level), based on the most recent information available concerning metal shrinkage due to LOX, was calculated. This should solve the problem on future Mercury-Redstone vehicles.

3. (C) TRAJECTORY

The following data was available for establishing the post flight trajectory:

3.25 - 131.5 sec	:	Theodolite
28.0 - 265.0 sec	:	FPS-16 Radar 1P.16
0.0 - 482.0 sec	:	Dovap

The actual trajectory was based on the following data:

0.0 - 415.0 sec	:	Dovap
415.0 sec to Impact	:	Computed ballistic trajectory using Dovap positions and velocities at 415.0 sec as initial conditions.

Mach number and dynamic pressure are based on measured Cape meteorological data to 31.4 km altitude in the ascent and adjusted to the 1959 ARDC atmosphere at 47.0 km. The 1959 ARDC atmosphere was used above 47.0 km in both ascent and descent. Grand Bahama Island atmosphere was used below 47.0 km in the descent. Mach number and dynamic pressure for the powered flight are shown in Figure 1.

Range, altitude and earth-fixed Z coordinate (lateral distance from the flight plane) are plotted versus range time in Figure 2. The time at which telemetry signal was lost is indicated on this figure. The actual and precalculated earth-fixed velocities are shown in Figure 3. Longitudinal acceleration for the powered flight is plotted in Figure 4.

The maximum load experienced during powered flight was 58.5 m/s^2 or about 1.5 m/s^2 higher than predicted and is consistent with the earlier cutoff time. Maximum values for earth-fixed velocity, longitudinal acceleration, Mach number and dynamic pressure during the ascent and descent are shown in Table I.

Conditions at Engine Cutoff

	Actual	Predicted	Act - Pred
Flight Time (sec)	141.71	142.50	-0.79
Altitude (km)	59.95	60.78	-0.83
Range (km)	38.37	37.70	0.67
Lateral Displacement (km)	.18	.34	-0.16
Earth-fixed Velocity (m/s)	1991.4	1974.8	16.6
*Longitudinal Velocity (m/s)	3257.1	3254.0	3.1
Lateral Velocity (m/s)	32.1	12.7	19.4
Local Pitch Trajectory Angle (deg)	42.11	41.69	0.42
Yaw Trajectory Angle (deg)	.95	.37	0.58

* Longitudinal velocity is the integration of the inertial acceleration along the missile axis.

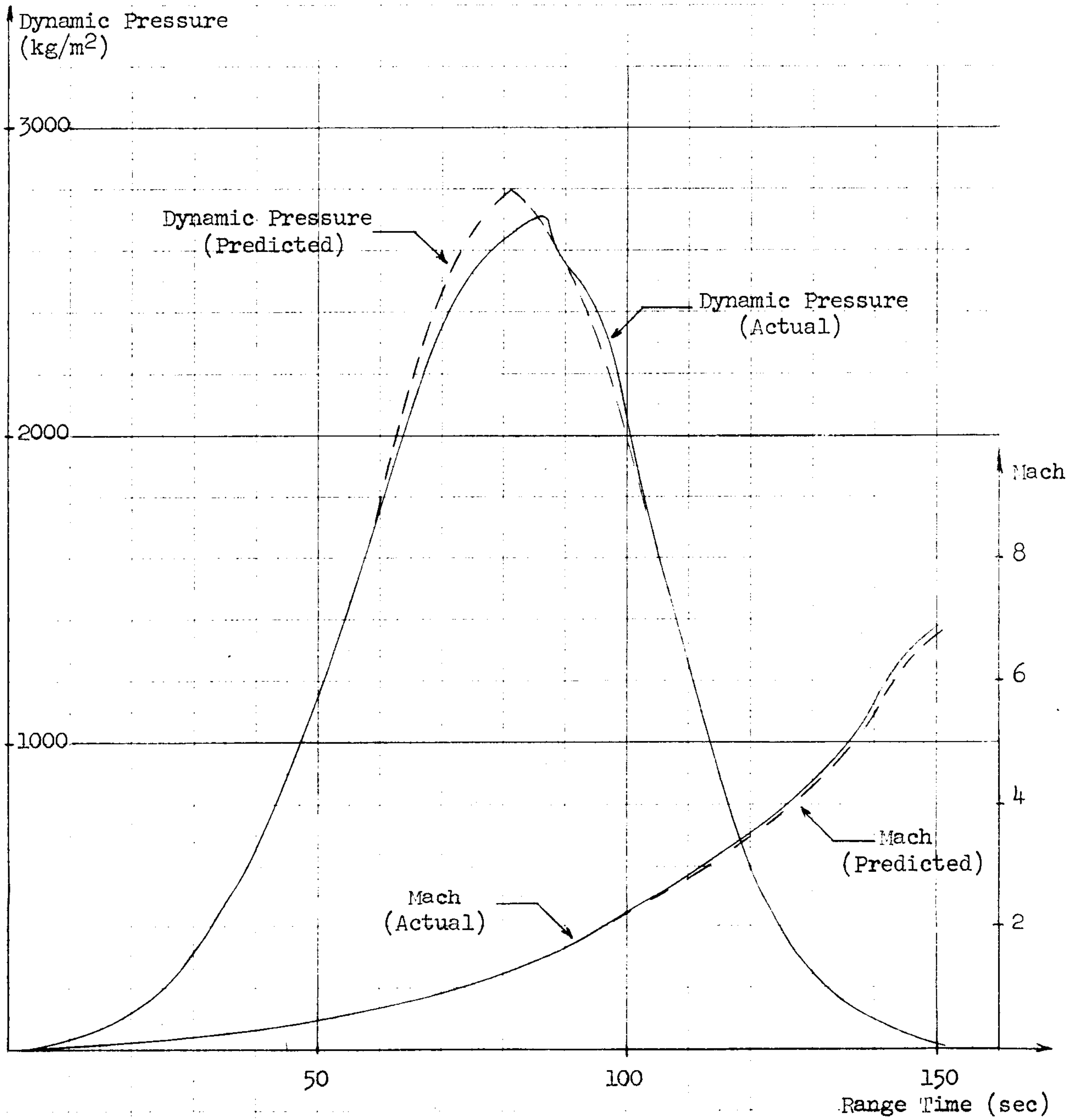

Fig. 1	DYNAMIC PRESSURE AND MACH NUMBER
MR-BD	

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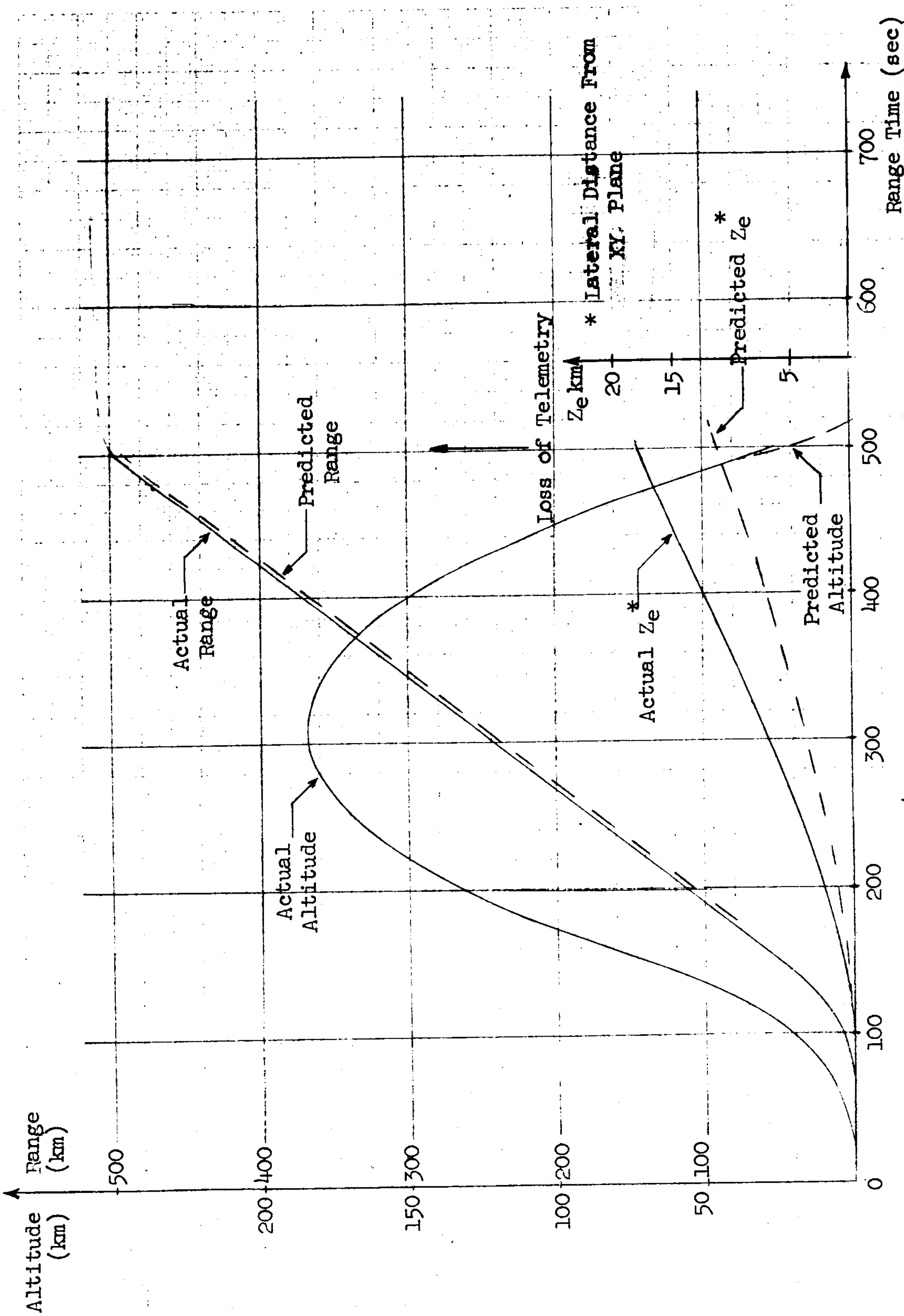

Fig. 2 MR-BD

TRAJECTORY

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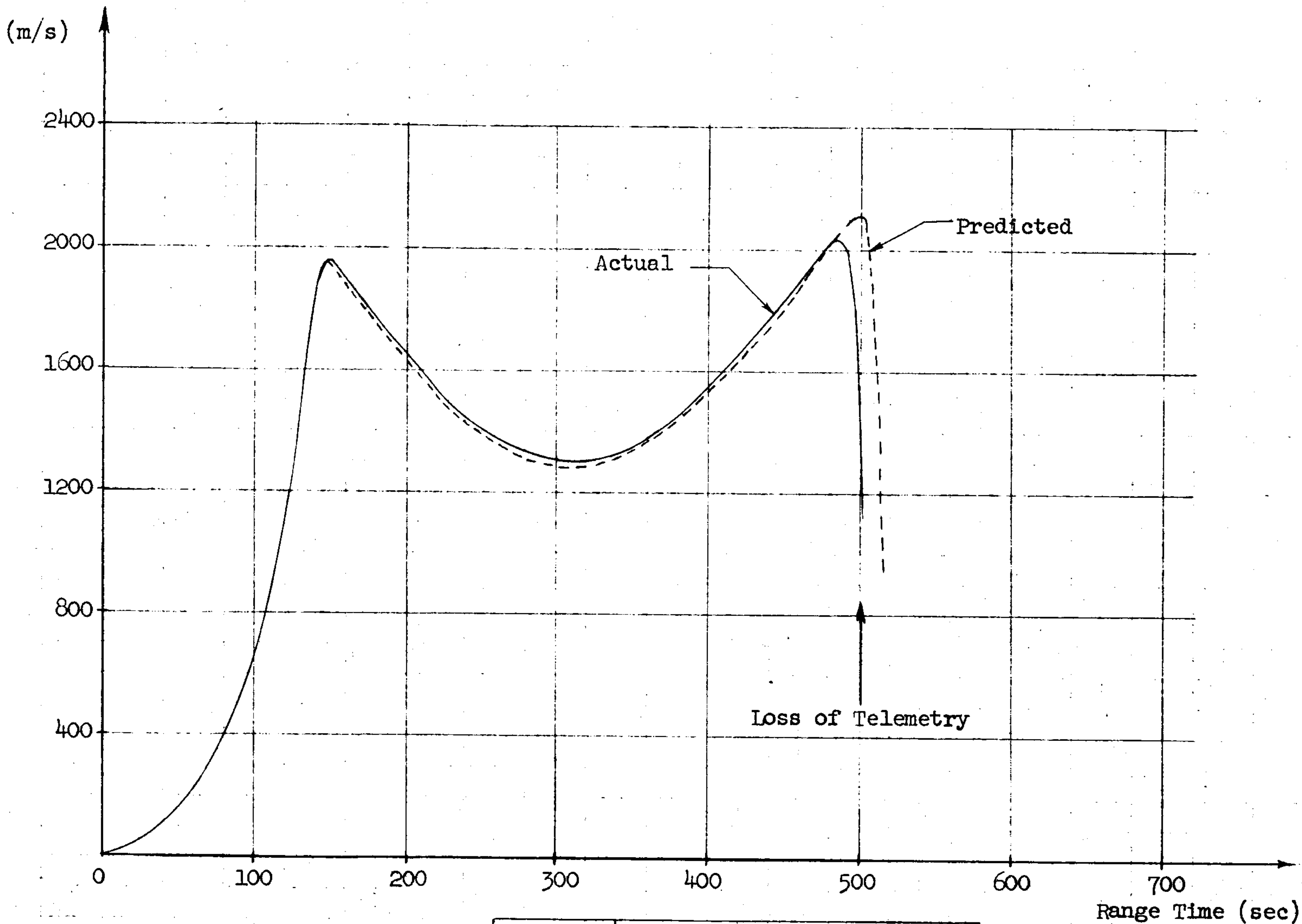

Fig. 3	
MR-BD	EARTH-FIXED VELOCITY

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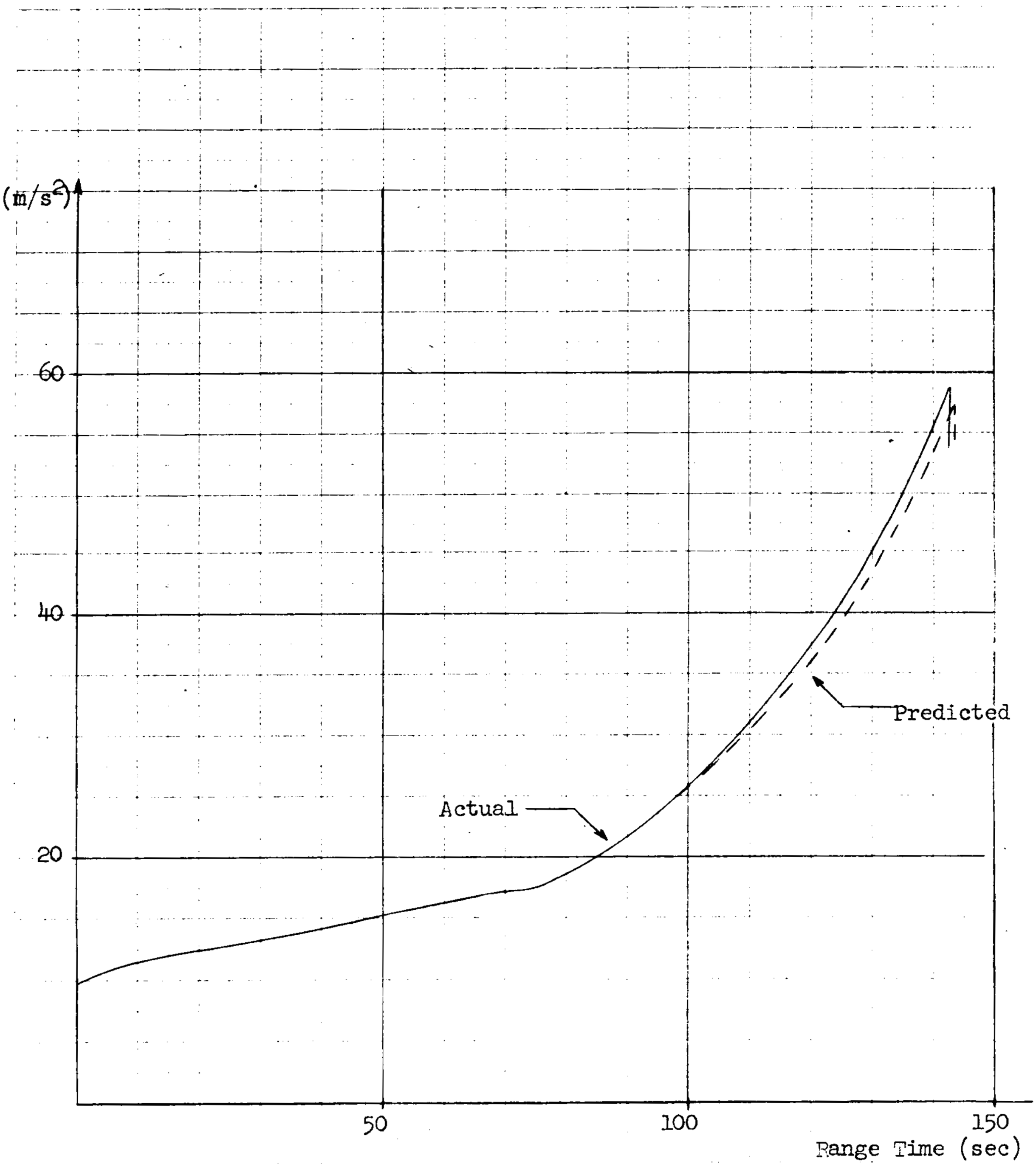

Fig. 4	
MR-BD	LONGITUDINAL ACCELERATION

[redacted]

The longitudinal velocity at cutoff was about 3.1 m/s higher than the value preset into the computer (see page 12).

The reference trajectory (Dovap) is compared with other tracking in Figure 5. The differences in position coordinates were small with a maximum average deviation in all tracking as follows:

$$\Delta X = 4 \text{ m} ; \qquad \Delta Y = 5 \text{ m} ; \qquad \Delta Z = 5 \text{ m}$$

An aerodynamic drag coefficient, consistent with an assumption of a tumbling body, was used in the calculation of the dive phase trajectory. Radiosonde winds from Grand Bahama Island were used from 33.3 km altitude to impact. For the purpose of this calculation, the capsule and booster were assumed to remain together and structurally intact until impact. Telemetry signal was lost from Cape Canaveral and GBI area at about the same time. Some trajectory parameters of the vehicle at this time are shown below.

Loss of Telemetry Signal

	Actual	Predicted	Act - Pred
Flight Time (sec)	500.71	*	0
Range (km)	501.11	494.56	6.55
Altitude (km)	25.17	20.37	4.80
Velocity (m/s)	1334.9	2108.0	-773.1
Dynamic Pressure (kg/m^2)	3550	19570	-16020
Deceleration (g's)	10.9	2.2	8.7

* Precalculated values at time of loss of telemetry.

The hypothetical impact of the booster-capsule configuration, assuming that structural integrity was maintained, is compared with the predicted impact point below.

	Miss Distances
Range (km)	2.7 over
Cross Range (km)	4.9 right
Radial (km)	5.6

The large cross range deviation is a result of the 20 m/s lateral velocity deviation at cutoff. The hypothetical and precalculated impact points are shown in Figure 6.

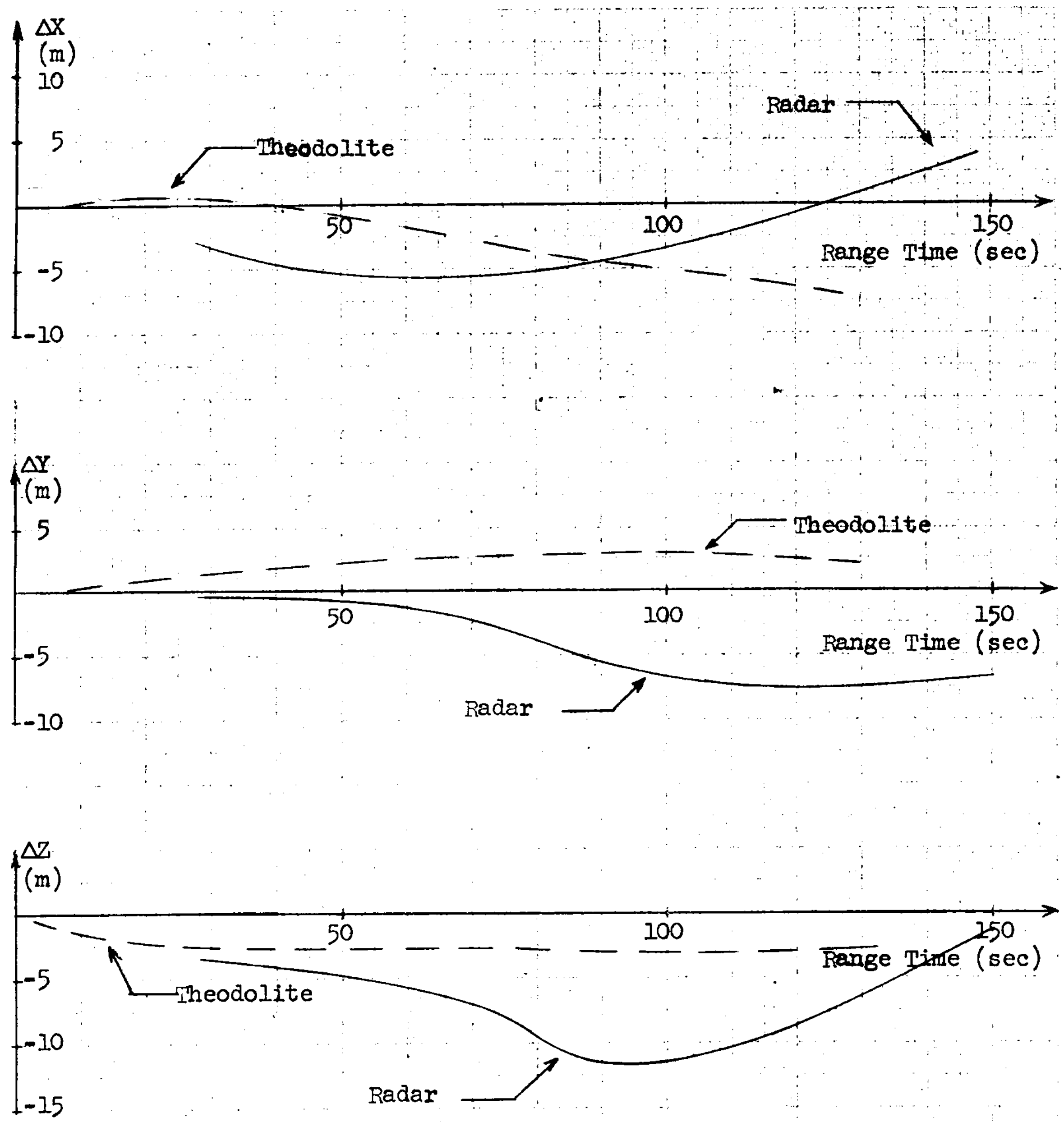

Fig. 5	TRACKING COMPARISONS (OTHER - REFERENCE)

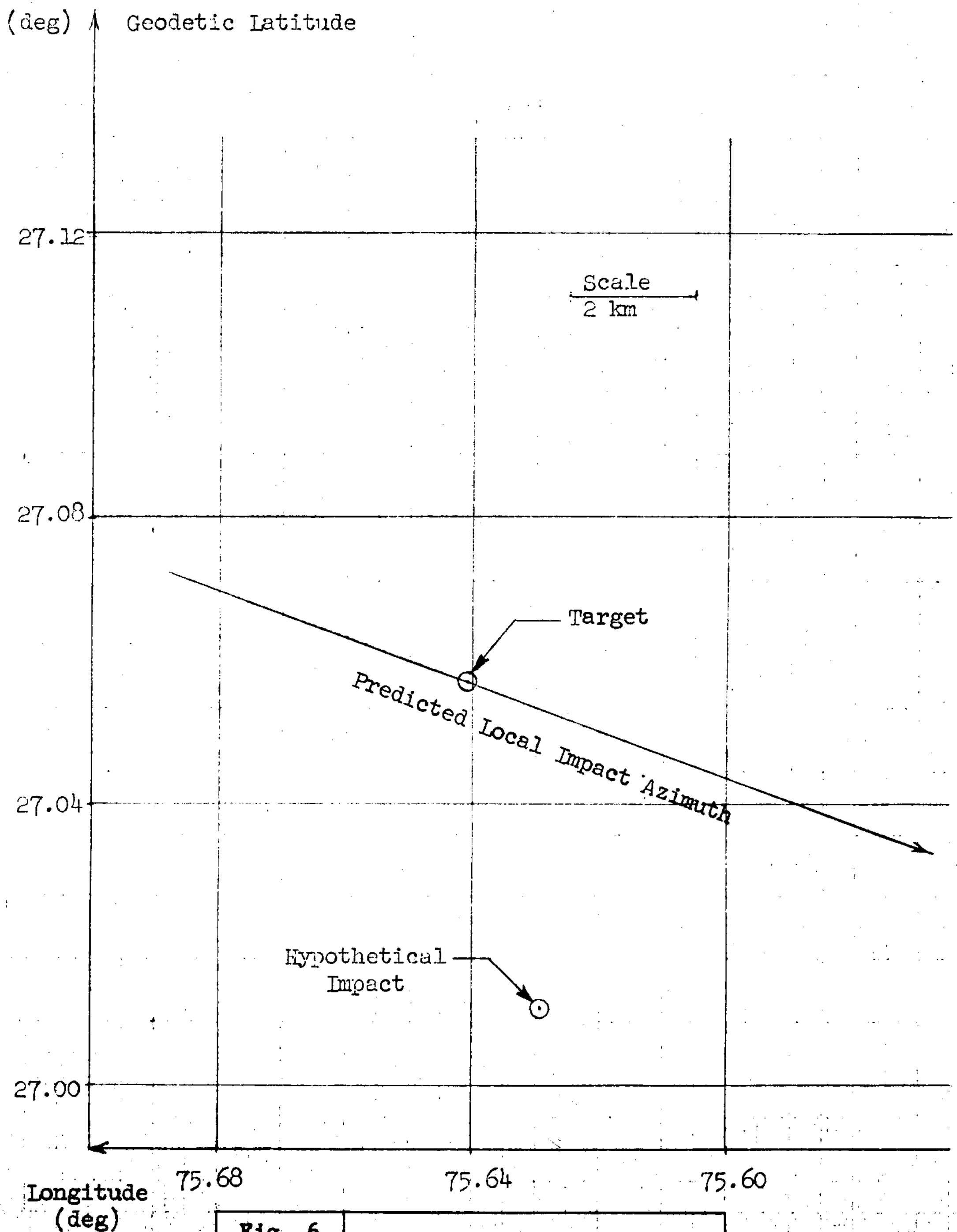

Fig. 6	
MR-BD	IMPACT AREA

4. (C) LONGITUDINAL VELOCITY AT CUTOFF

Cutoff was scheduled to occur when the integral of the longitudinal acceleration (hereafter called longitudinal velocity) reached 3253.98 m/sec. The telemetered longitudinal velocity at cutoff was 3257.1 m/sec or about 3.1 m/sec higher than intended. This 3.1 m/s velocity deviation, which is approximately 0.1% error and within the specifical measuring instrument tolerance (0.1%), represents a functional error of the measurement. This velocity increase would cause an increase of about 1.2 km in range and less than 0.2 m/s^2 increase in maximum deceleration. The longitudinal velocity was also computed from external tracking data. The difference between the telemetered and computed longitudinal velocity is plotted versus time in Figure 7. The maximum difference between the two was only 3.3 m/s or about 0.1% which represents the total intelligence error in the measurement. A part of this difference may be due to small errors in the trajectory parameters and in the necessary telemetered data reduction. The functional and intelligence errors are completely independent and in this particular case are compensating.

5. (C) PERFORMANCE OF PROPULSION SYSTEM

Mercury-Redstone MR-BD used LOX and alcohol as propellants; the predicted values used were taken from References 1 and 2. The earth-fixed velocity and slant distance to the vehicle at 137 seconds range time were used to perform the usual ballistic evaluation for thrust, flow rate, and specific impulse.

The vehicle weights and their comparison with predicted values are given in Table III. The propellant filling weights are taken from Reference 3. Due to a malfunction in the LOX ΔP tanking system (see page 3), the predicted LOX tanking weight was used in all calculations. Table IV contains a complete comparison of actual and predicted power plant parameters.

Some of the more important engine parameters and their deviation from the corresponding predicted values are given below. The values given are those that most closely represent the actual performance of the entire power plant.

	Actual	% Deviation from Predicted
Sea Level Thrust (lb)	78,780	+1.00
Sea Level Specific Impulse (sec)	216.32	-0.60
Total Flow Rate (lb/sec)	364.19	+1.60

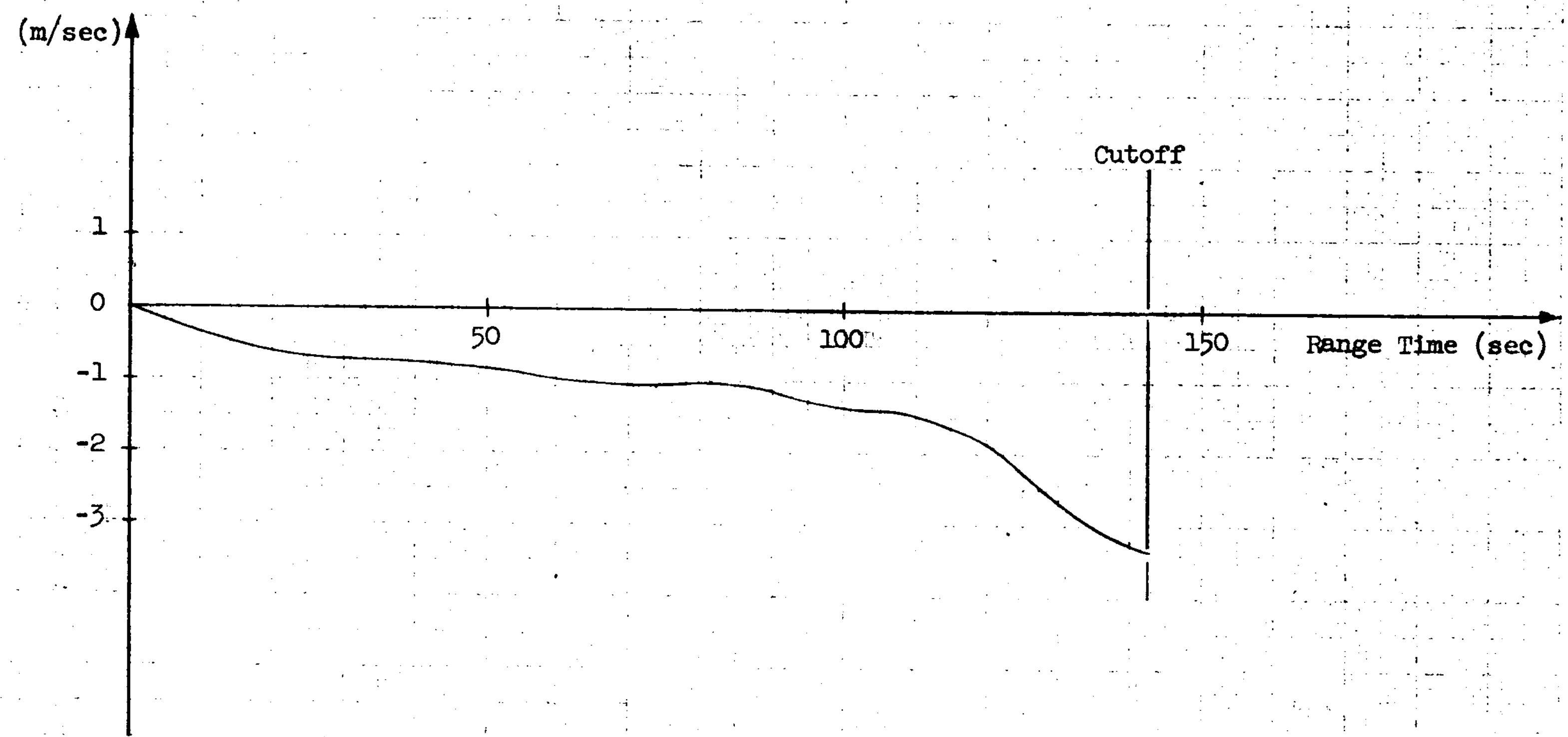

Fig. 7	LONGITUDINAL VELOCITY COMPARISON (TELEMETERED - TRAJECTORY)
MR-BD	

The time between liftoff and cutoff (flight time) as computed from the ballistic evaluation and the measured liftoff weight is only 0.09 seconds shorter than indicated by telemetry.

A ballistic evaluation, using the measured liftoff weight, was computed to satisfy the conditions that the earth-fixed velocity be 1728 m/sec and the slant distance to the vehicle be 61.187 km at 137 seconds range time. In Figure 8, the solid line represents the difference between the earth-fixed velocity from external tracking and the earth-fixed velocity computed from the ballistic evaluation. The dashed line represents the difference between the earth-fixed velocity from external tracking and the earth-fixed velocity computed from the telemetered engine parameters.

Two independent measurements were made of the thrust chamber pressure, Giannini and error signal to thrust controller. These two measurements and the predicted chamber pressure are plotted in the upper portion of Figure 9. The average telemetered thrust chamber pressures are compared with predicted below.

	Average (psia)	% Deviation from Predicted
Predicted	317.5	-
Error Signal	317.21	-0.09
Giannini	315.54	-0.62

The chamber pressure derived from the ballistic evaluation is 3.60 psia (1.14%) higher than the Giannini measurement. This is well within the measuring accuracy of the Giannini gage.

The fuel flow, LOX flow, total flow, and mixture ratio are shown in Figures 10 and 11. The total flow rate includes the hydrogen peroxide flow rate and the amount of LOX vented. The measured mixture ratio was used to obtain a fuel and LOX flow rate from the ballistic evaluation. The telemetered flow rates are compared with predicted below.

	Predicted	Measured	% Deviation from Predicted
Fuel Flow Rate (lb/sec)	157.30	156.26	-0.66
LOX Flow Rate (lb/sec)	194.80	197.13	+1.20
Total Flow Rate (lb/sec)	358.45	359.69	+0.34

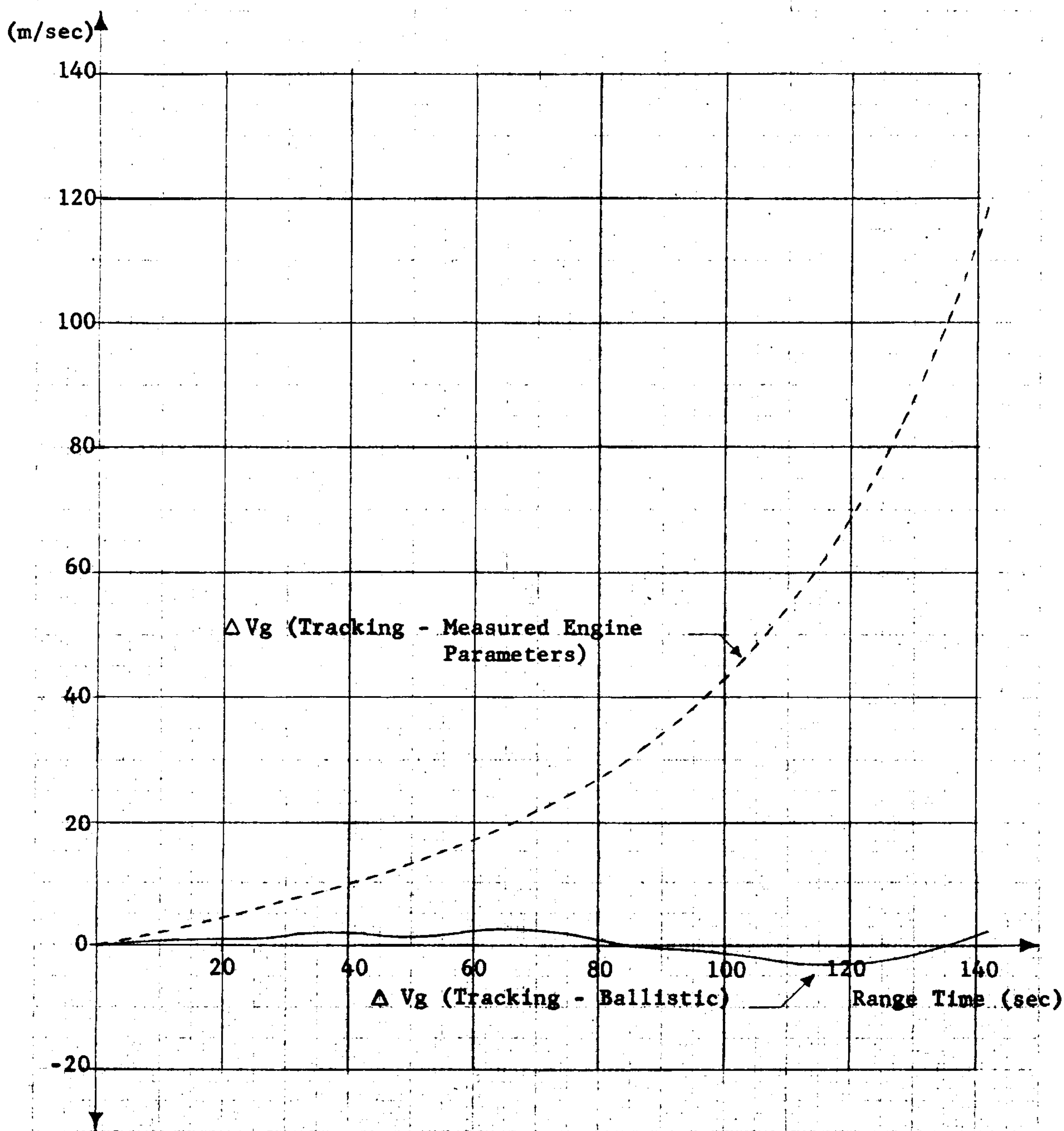

Fig. 8	EARTH-FIXED VELOCITY DIFFERENCES
MR-BD	

[redacted]

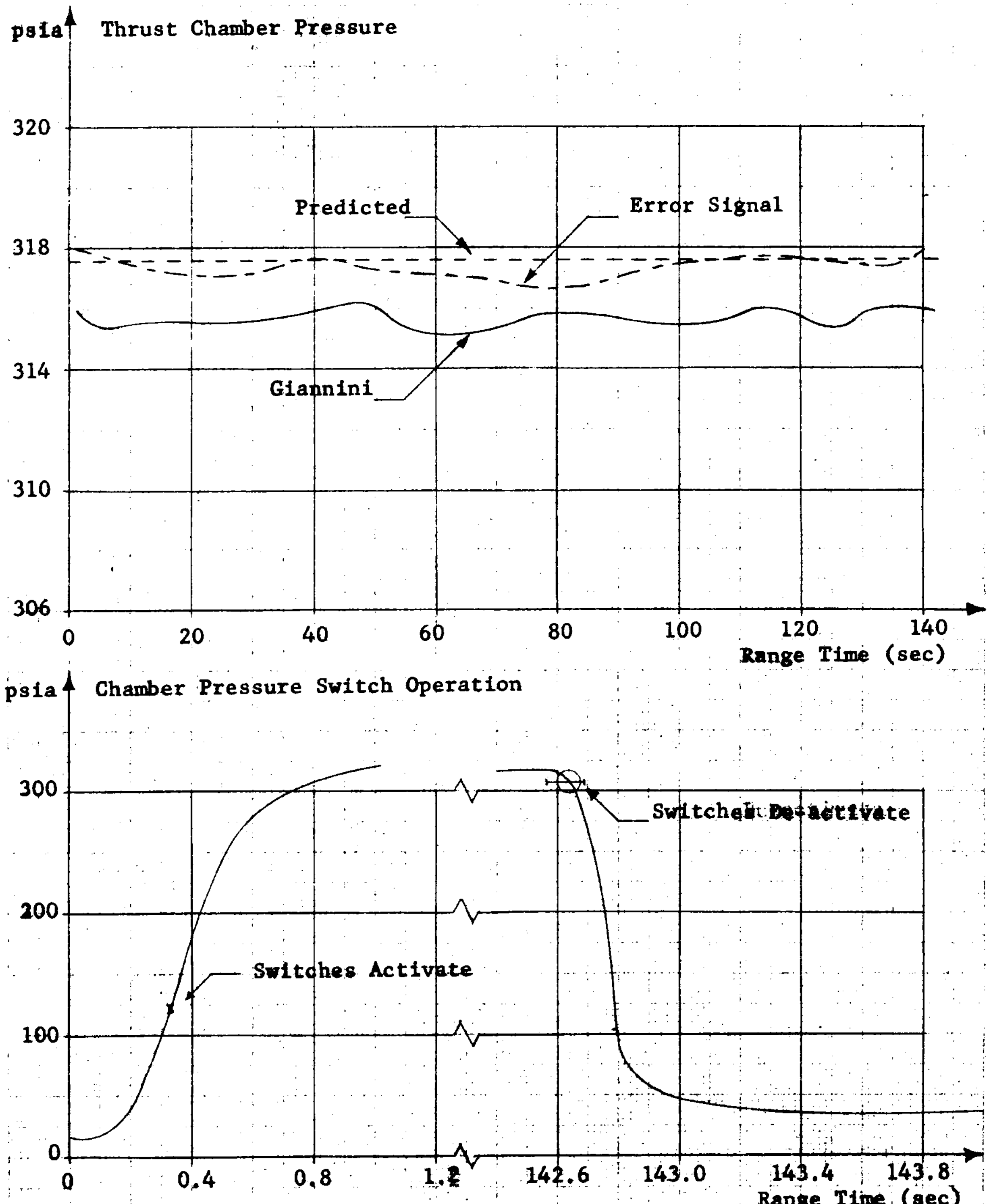

Fig. 9	THRUST CHAMBER PRESSURE
MR-BD	

[redacted]

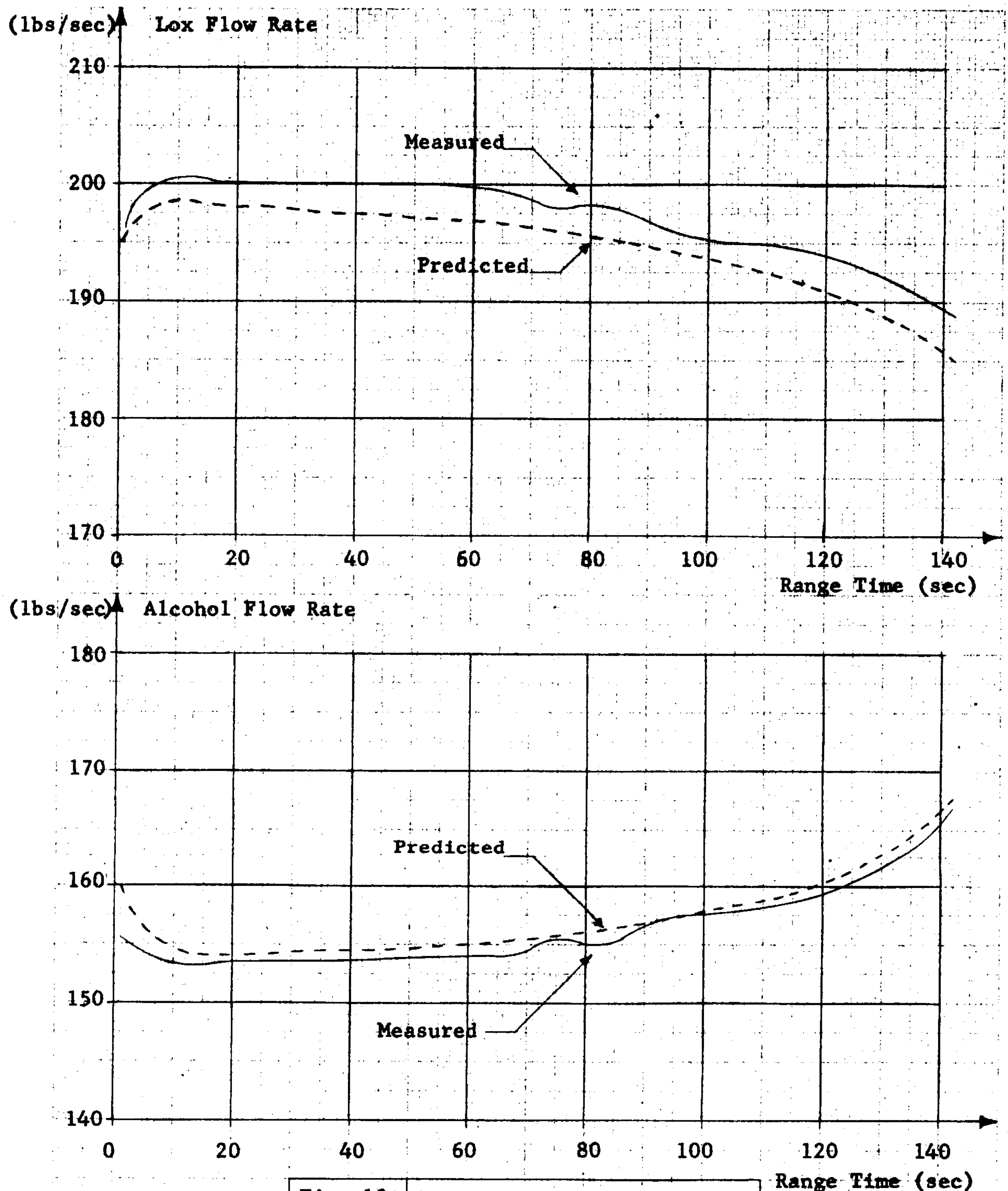

Fig. 10	LOX AND ALCOHOL FLOW RATES
MR-BD	

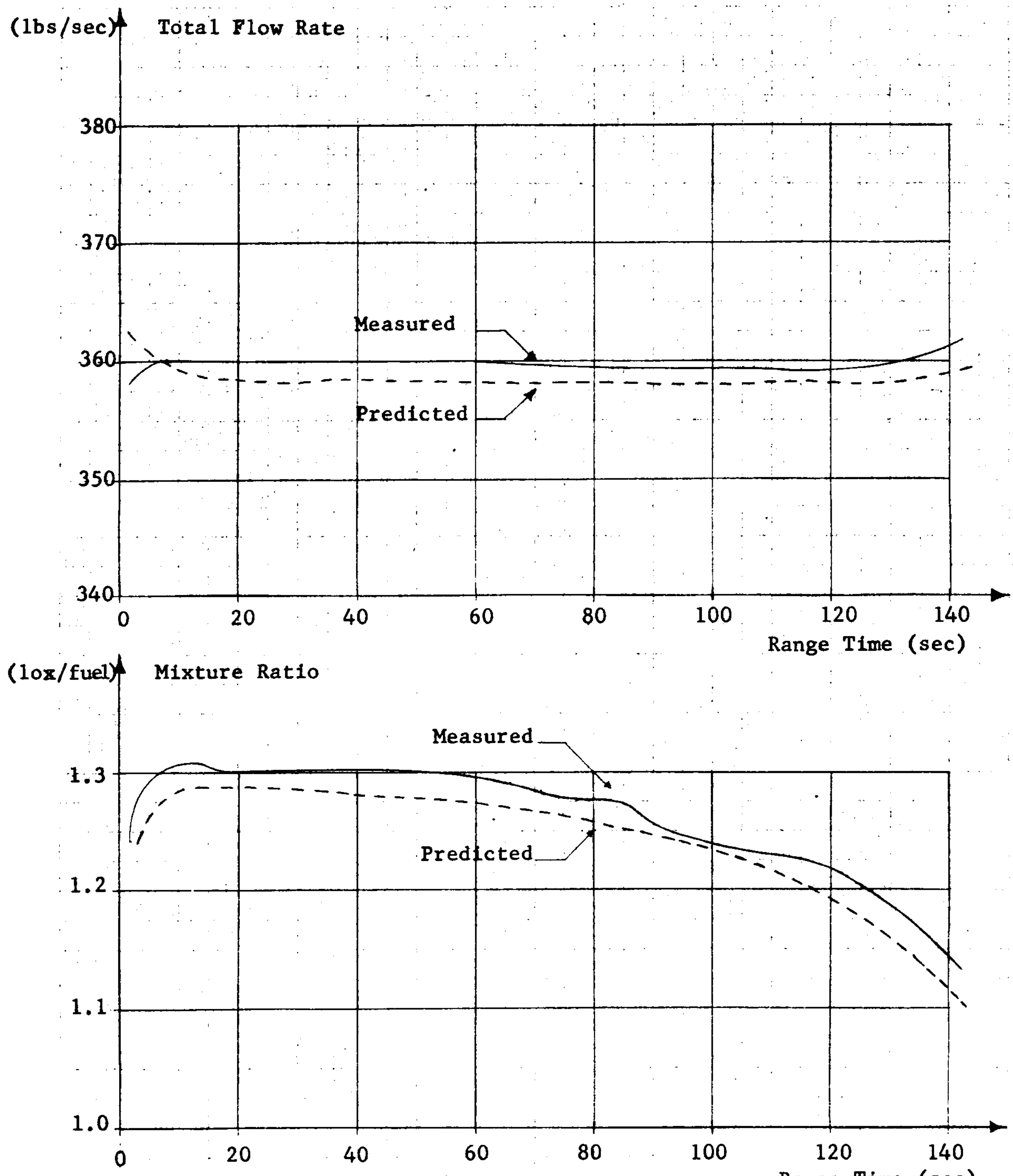

Fig. 11	TOTAL FLOW RATE AND ENGINE MIXTURE RATIO
MR-BD	

Table IV contains a complete comparison of actual and predicted power plant parameters.

Performance of the combustion chamber pressure control system was satisfactory. The chamber pressure (page 16) was generally constant during flight, indicating close control by the controller system. The chamber pressure measured by the Giannini gage and the pressure derived from the controller error signal agree within the accuracy of instrumentation. The H_2O_2 servo valve position for this flight is compared with the same measurement on MR-1A in Figure 12. The valve position followed the expected trend of a controlled engine and indicates satisfactory performance of the control system.

The H_2O_2 tank pressurization was as expected throughout flight. Blockhouse records of the pressure immediately downstream of the pneumatic regulator indicated the pressure was stable during the countdown. Just prior to ignition the pressure was 570 psig which agrees with the recommended regulator setting. The H_2O_2 tank pressure, shown in Figure 12, remained relatively constant during flight and agrees closely with the predicted pressure.

6. (C) CONTROL

The vehicle was properly controlled throughout the powered flight. Figures 13 through 16 show the telemetered jet vane deflections (solid line). The vane deflections calculated from the control equations (circled points) are shown for comparison. The vane deflections before cutoff did not exceed 25% of the total deflection possible.

The telemetered angular velocities and angular positions are shown in Figures 17 through 20. The telemetered gyro yaw position indicates a constant bias to the right. A close analysis of the vehicle angular motion and control equations shows that this bias is not a true vehicle attitude but is attributed to telemetering error. In view of this, an adjusted axis is shown as a dashed line in Figures 19 and 20. The values from this axis should be considered the most likely true values.

The right hand portion of Figure 20 displays the gyro pitch and roll position using a smaller scale to show conditions existing 10 seconds after cutoff (separation time for normal Mercury-Redstone flight). The pitch attitude is caused by a pitching motion due to venting LOX and agrees with predicted values.

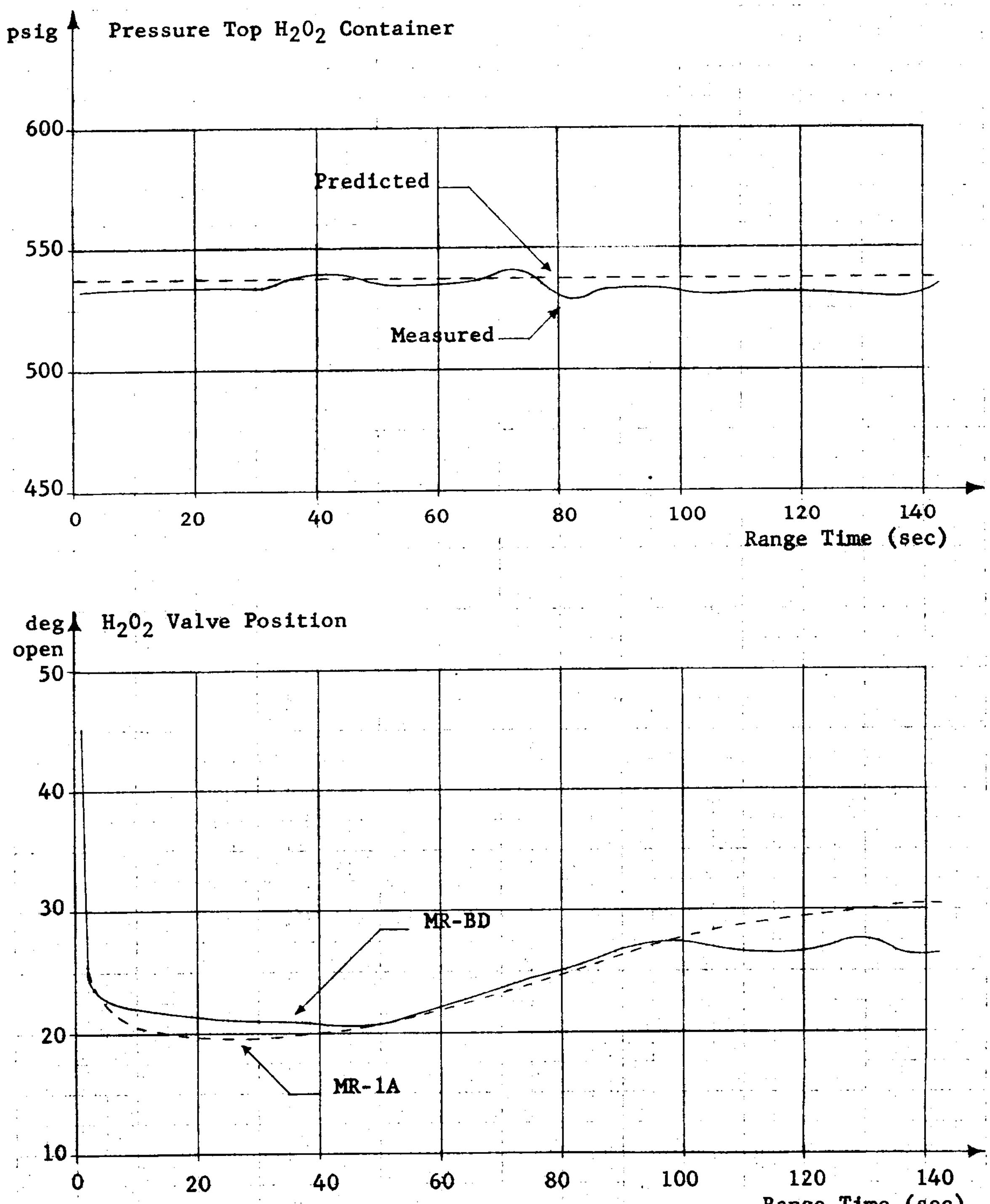

Fig. 12	PRESSURE TOP H_2O_2 CONTAINER AND H_2O_2 VALVE POSITION
MR-BD	

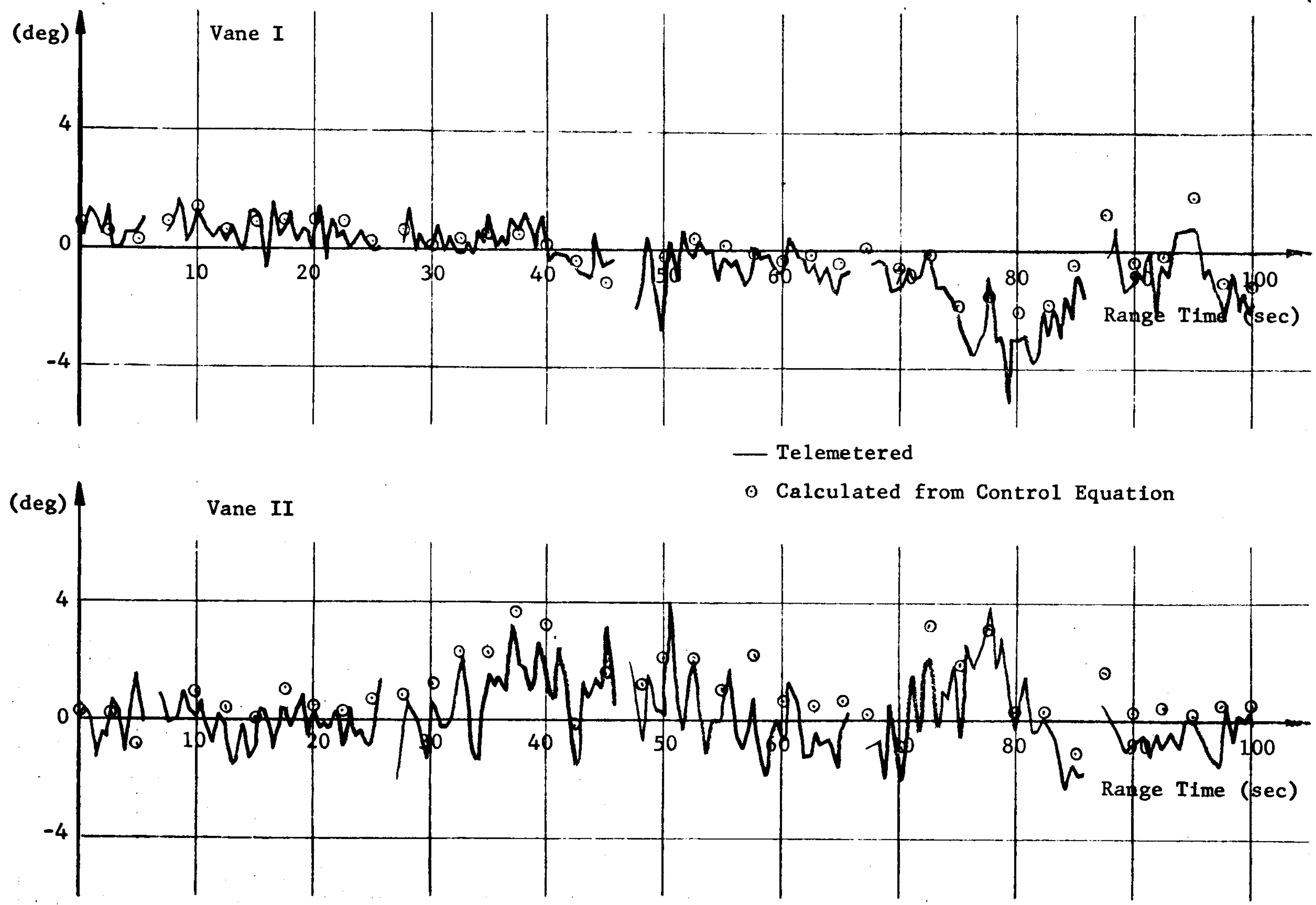

Fig. 13	CALCULATED & TELEMETERED VANE DEFLECTIONS (0 - 100 SEC)
MR-BD	

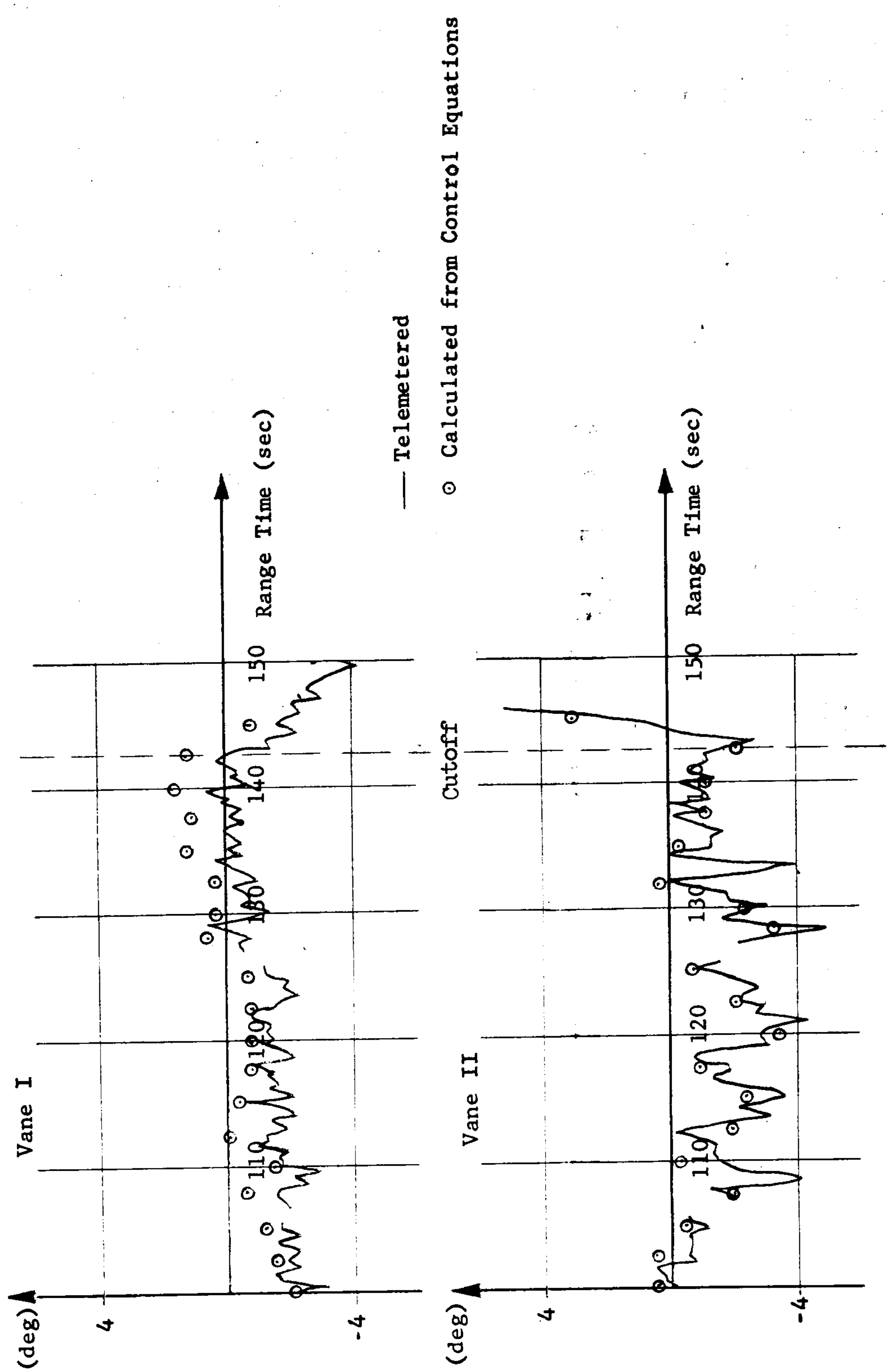

Fig. 14 MR-BD
CALCULATED & TELEMETERED VANE DEFLECTIONS (100 - 145 SEC)

[redacted]

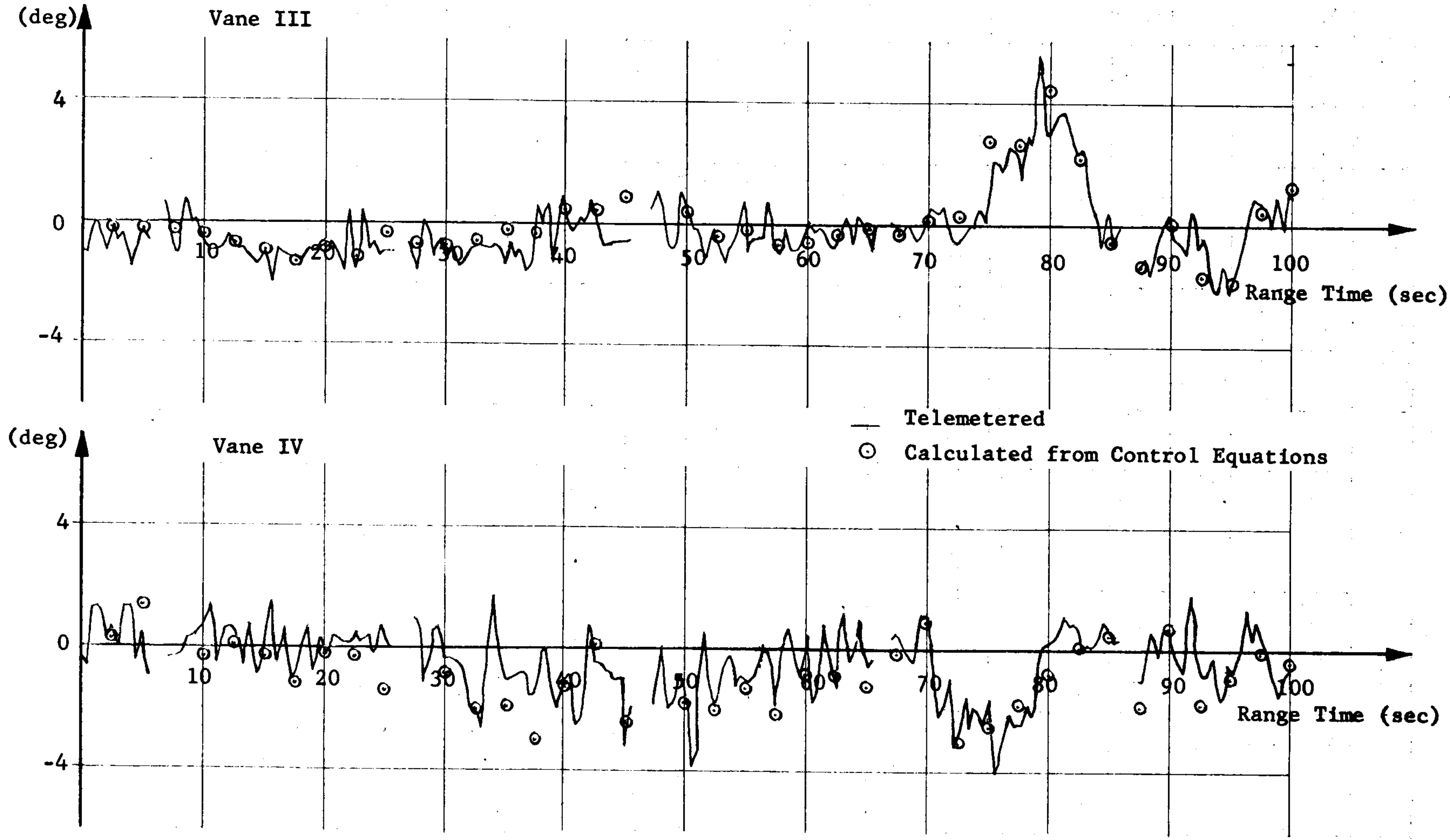

Fig. 15	CALCULATED & TELEMETERED VANE DEFLECTIONS (0 - 100 SEC)
MR-BD	

[redacted]

[redacted]

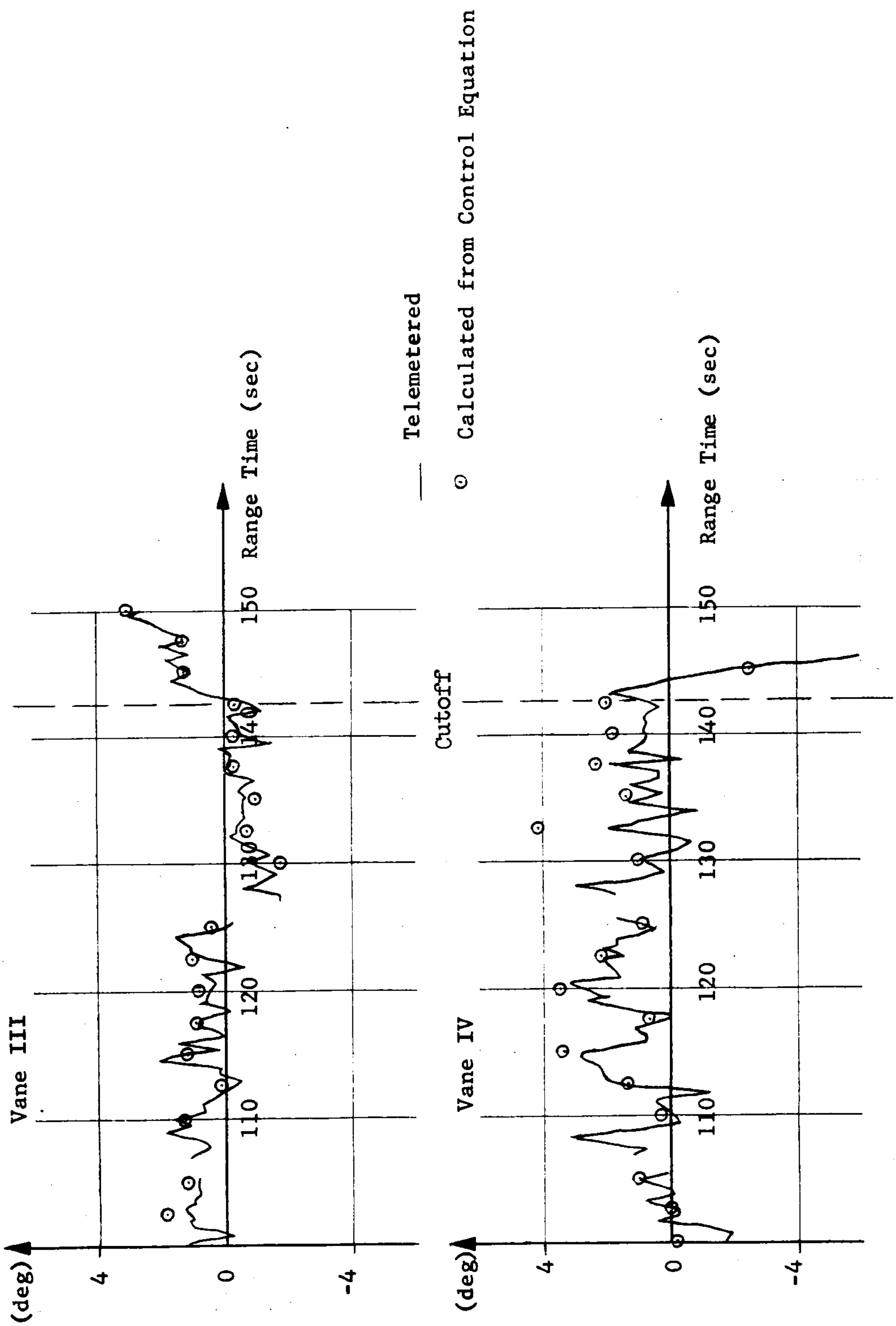

Fig. 16

MR-BD

CALCULATED & TELEMETERED VANE DEFLECTIONS (100 - 145 SEC)

[redacted]

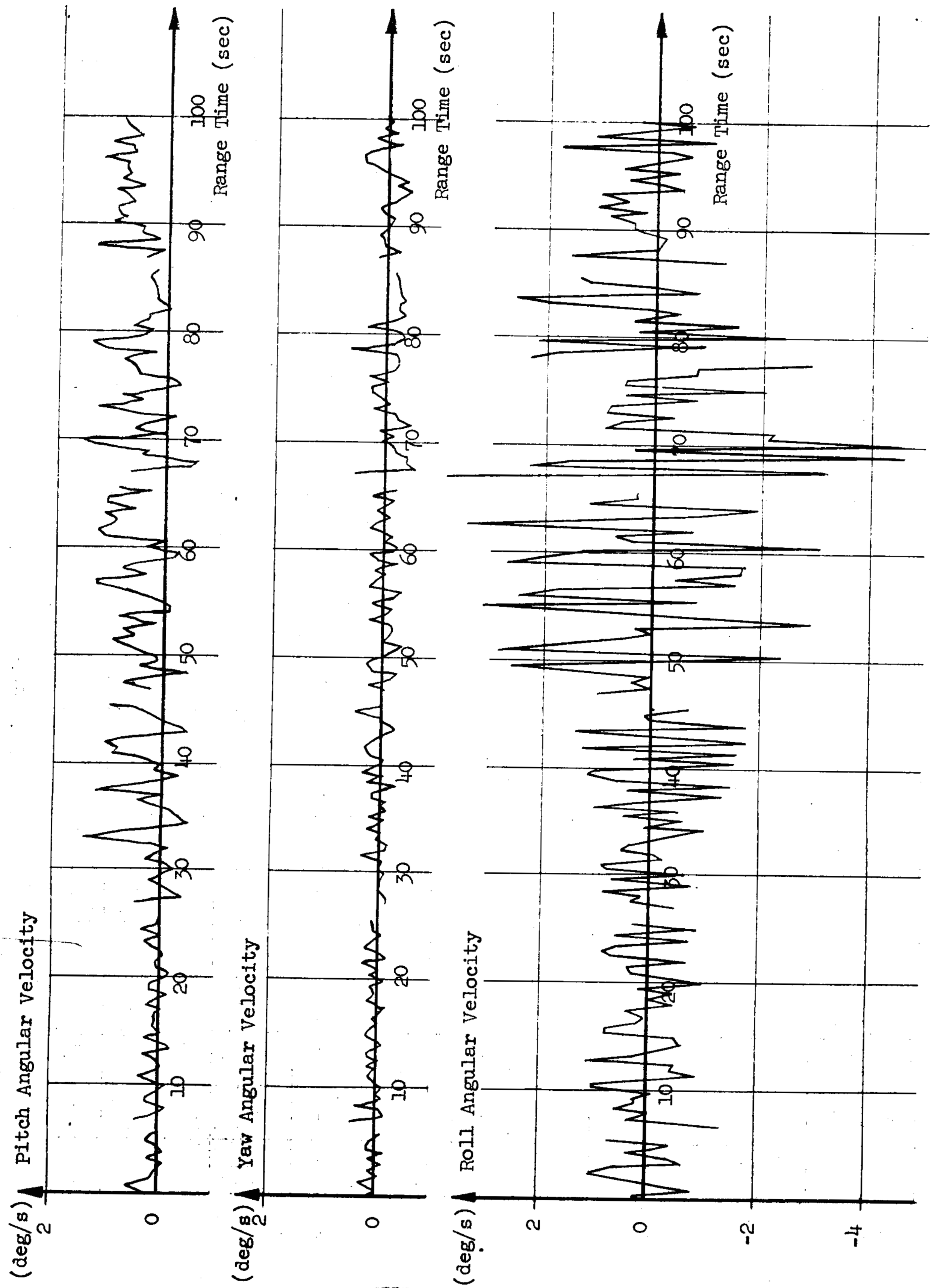

Fig. 17 MR-BD TELEMETERED ANGULAR VELOCITIES (0 - 100 SEC)

[redacted]

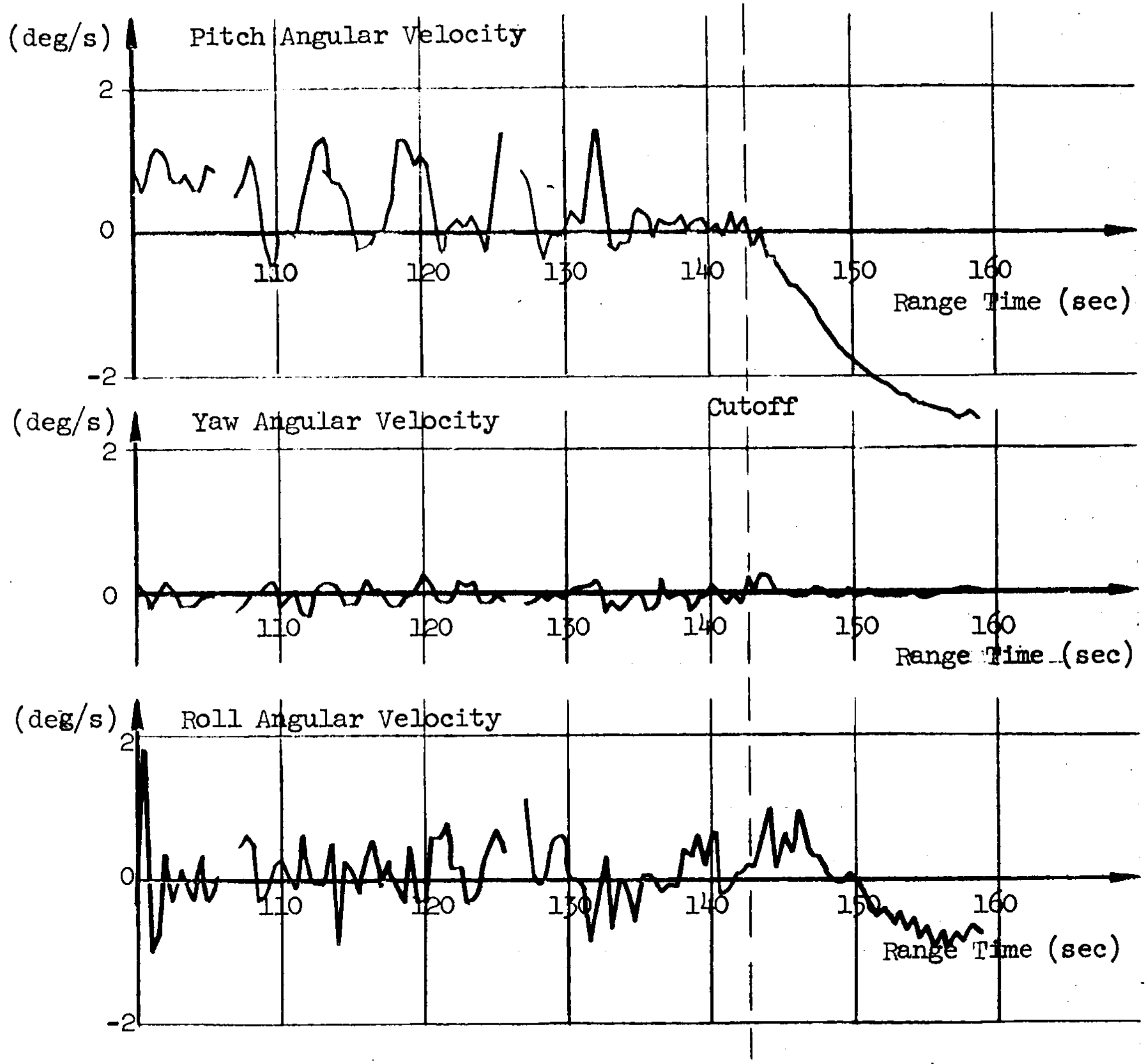

Fig. 18	TELEMETERED ANGULAR VELOCITIES (100 - 160 SEC)
MR-BD	

[redacted]

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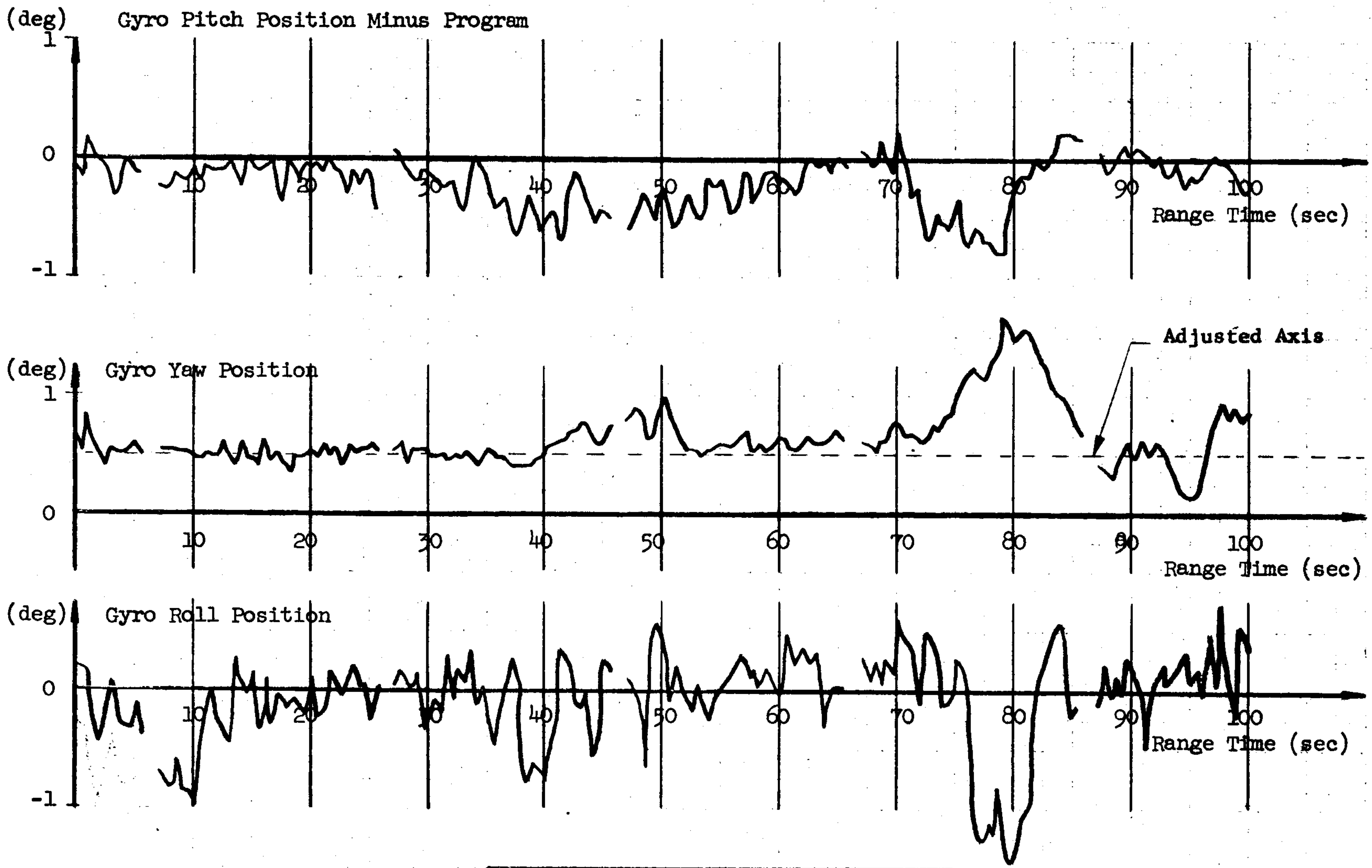


Fig. 19	TELEMETERED ATTITUDE ANGLES (0 - 100 SEC)
MR-BD	

[redacted]

[redacted]

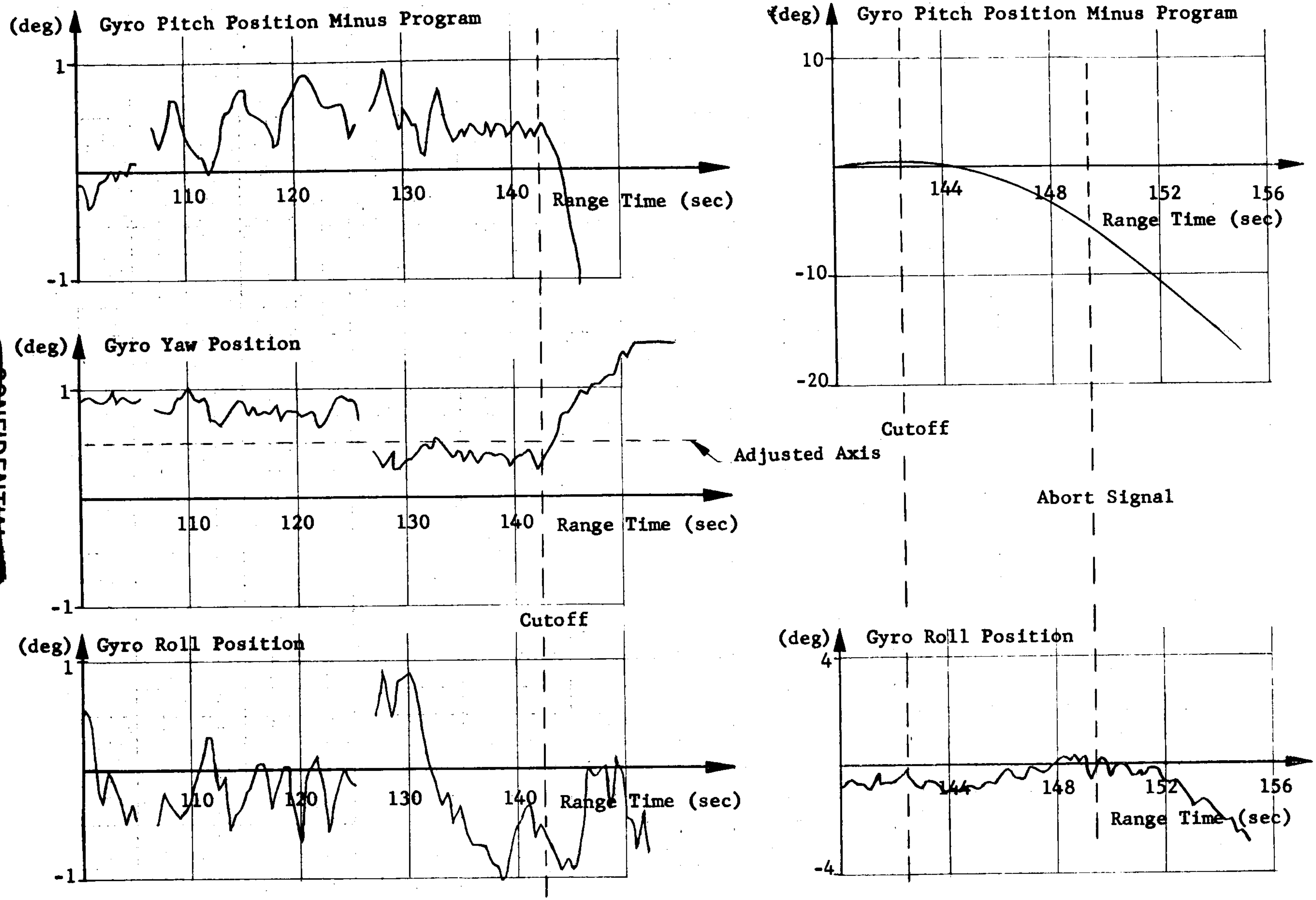


Fig. 20	TELEMETERED ATTITUDE ANGLES (100 - 145 SEC) (140 - 155 SEC)
MR-BD	

[redacted]

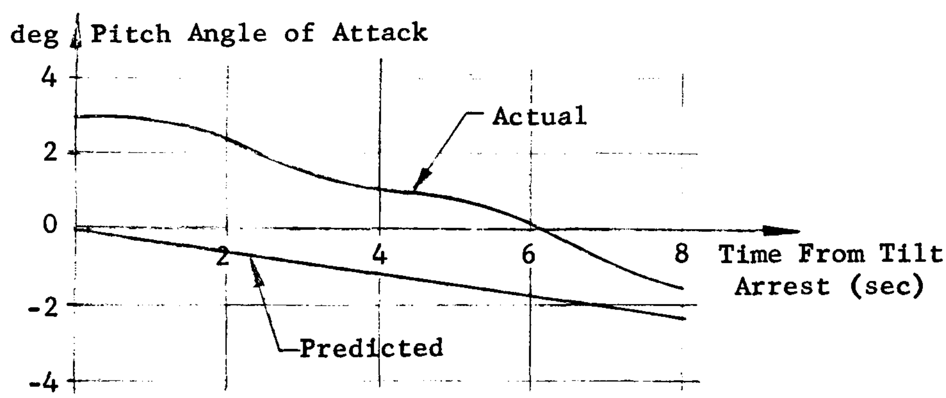
The attitude angles and angular velocities at 10 seconds after cutoff were as follows:

Gyro pitch position minus program (deg)	-12.0
Gyro yaw position (deg)	0.9
Gyro roll position (deg)	-0.8
Angular velocity - pitch (deg/sec)	-2.1
Angular velocity - yaw (deg/sec)	0
Angular velocity - roll (deg/sec)	-0.6

The tilt program (Figure 21) was as predicted throughout flight. The final angle was 41 degrees.

A temporary hold in the tilt program was made during the high dynamic pressure region of flight. During this hold, the attitude of the vehicle remained at about 20 degrees from the launch vertical for about 8 seconds (between 79.1 and 87.2 seconds range time). Preliminary calculations indicate that arresting the tilt program is not a sufficient maneuver to reconfirm the control stability of the Mercury-Redstone configuration.

The predicted angle of attack build-up due to this tilt arrest is -2.3 degrees (relative wind from lower side) for the nominal trajectory. At the time of tilt arrest on MR-BD, the pitch angle of attack calculated from winds was about 3 degrees (relative wind from top side). The angle of attack calculated from winds at the end of this maneuver was -1.5 degrees. The angle of attack maneuver was about as expected, considering effects of both the wind and tilt arrest. The calculated angle of attack is compared with the predicted value below referenced from time of tilt arrest.



The radiosonde wind components are shown in Figure 22.

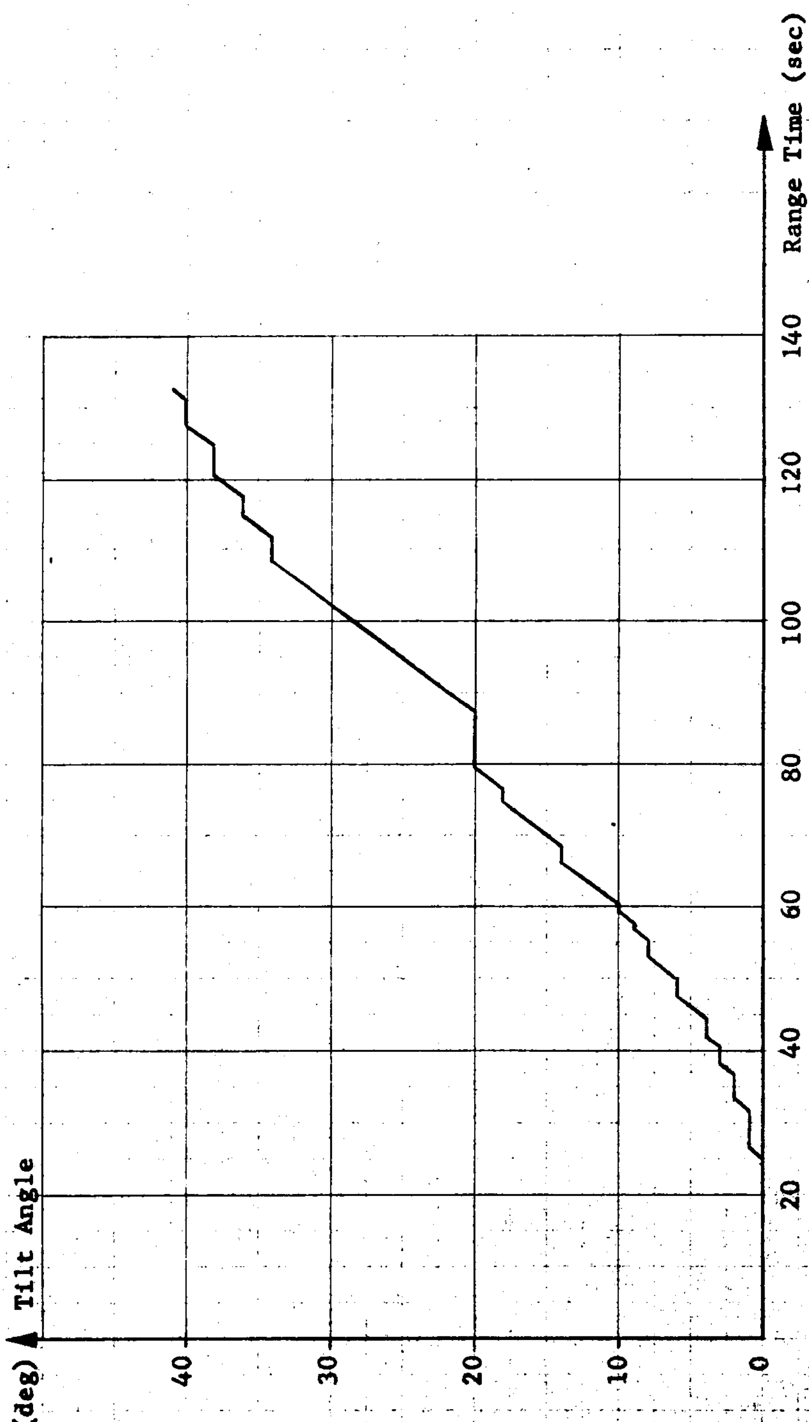


Fig. 21 MR-BD

TILT PROGRAM

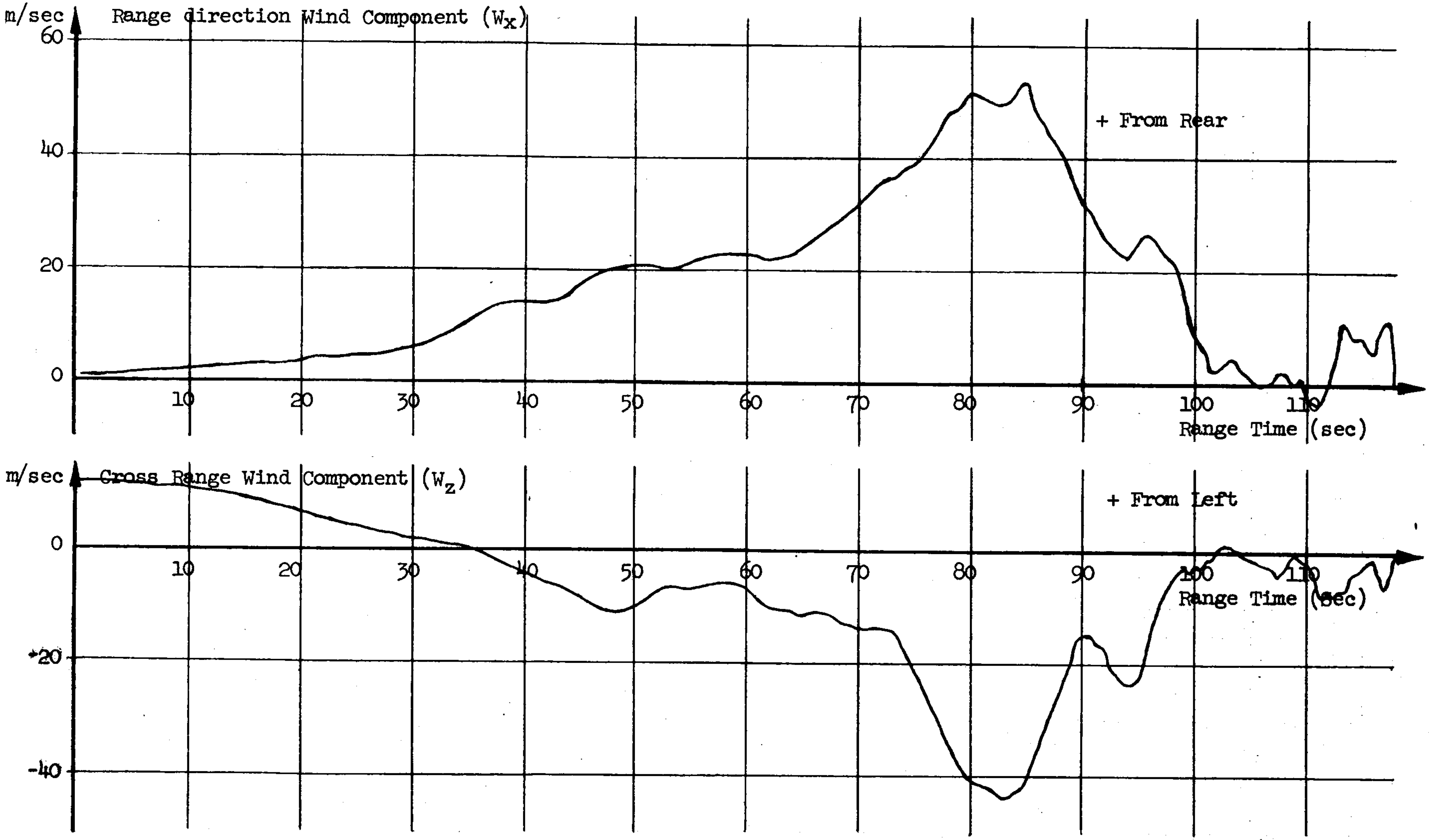


Fig. 22	RADIOSONDE WINDS (0 - 110 Sec)
MR-BD	

7. (C) VEHICLE OSCILLATIONS

Oscillations at second bending mode frequencies were observed in the angular velocities and the low frequency vibration measurement (950) which was located over fin IV at Station 38.5 (forward most ring of instrument compartment). A filter network had been added to the control system of MR-BD to dampen any excitation of the second bending mode. Figure 23 shows the peak to peak amplitude of this vibration measurement and the lower portion of the figure shows the predominate frequency of the measurement. The period between 45 and 60 seconds is not represented in Figure 23 because the character of the vibrations during this time was considerably changed. A greater magnitude of vibrations in the higher frequencies were present during this time. Observed bending mode frequencies between liftoff and cutoff are shown in Figure 24. The observed frequencies are in close agreement with the predicted second bending frequencies.

At approximately 120 seconds the frequency of oscillations on measurement 950 changes from 7.7 cps to a frequency of about 1.5 cps. The source of this oscillation was determined to have been propellant sloshing. It does not show up at an earlier time because the most probable time for the fuel to slosh is when the fuel level is between the vehicle center of percussion and the center of gravity. This period occurs after 90 seconds. The observed sloshing frequency is shown as circled points in Figure 24 and compares very closely with the predicted values (solid line).

The calculated rigid body control frequency is shown in Figure 24 for comparison purposes.

The oscillations in the angular velocities due to the second bending mode reached a maximum amplitude between 100 and 135 seconds. The table below shows the maximum amplitudes for the angular velocities and also for the jet vane deflections which occurred on MR-1A, MR-2 and MR-BD.

	Maximum Amplitude of φ's (deg/sec)	Maximum Amplitude Jet Vane Deflections
MR-1A	1.1	2.9
MR-2	0.35	0.8
MR-BD	0.15	.45

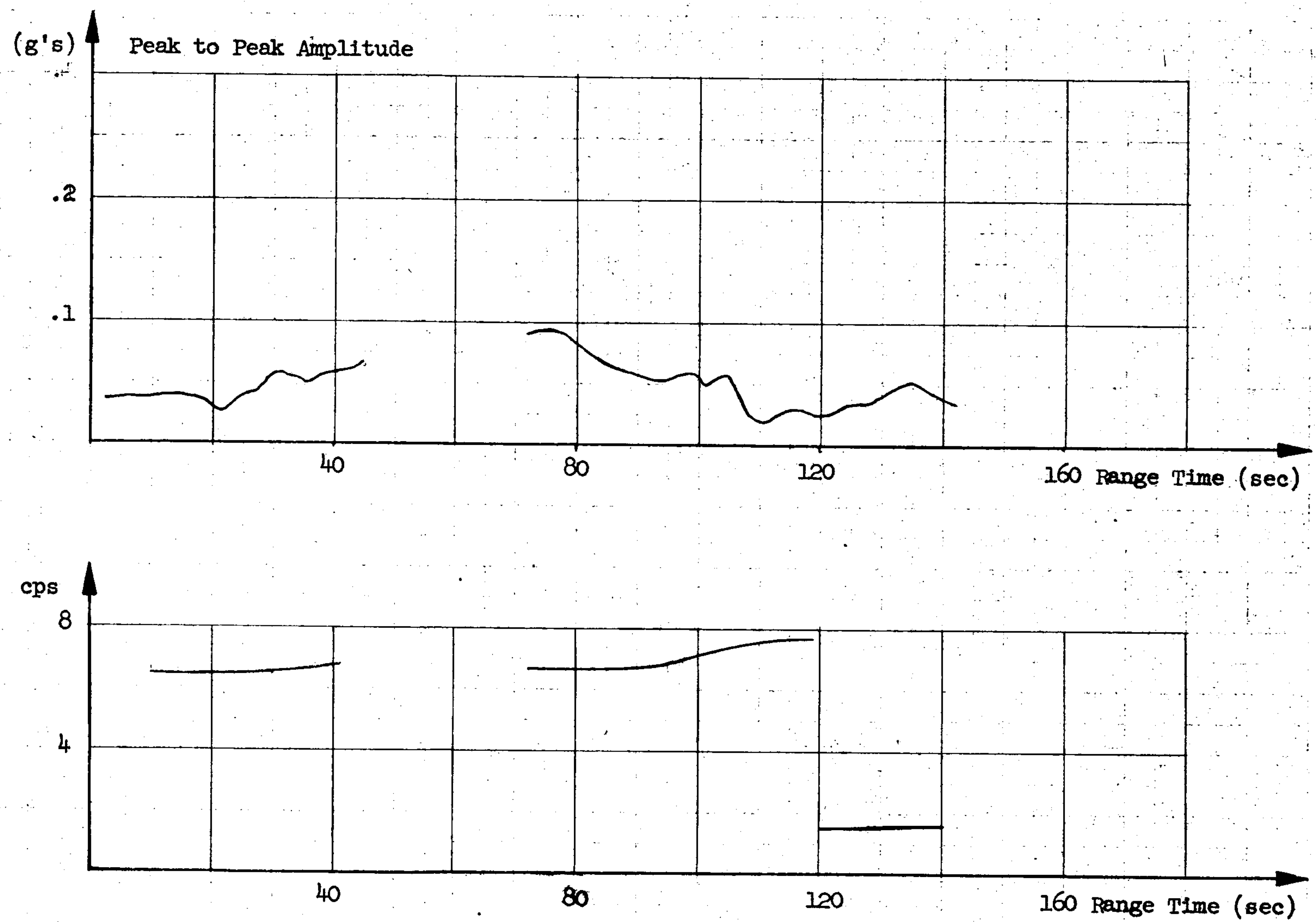


Fig. 23	LOW FREQUENCY VIBRATION MEASUREMENT
MR-BD	

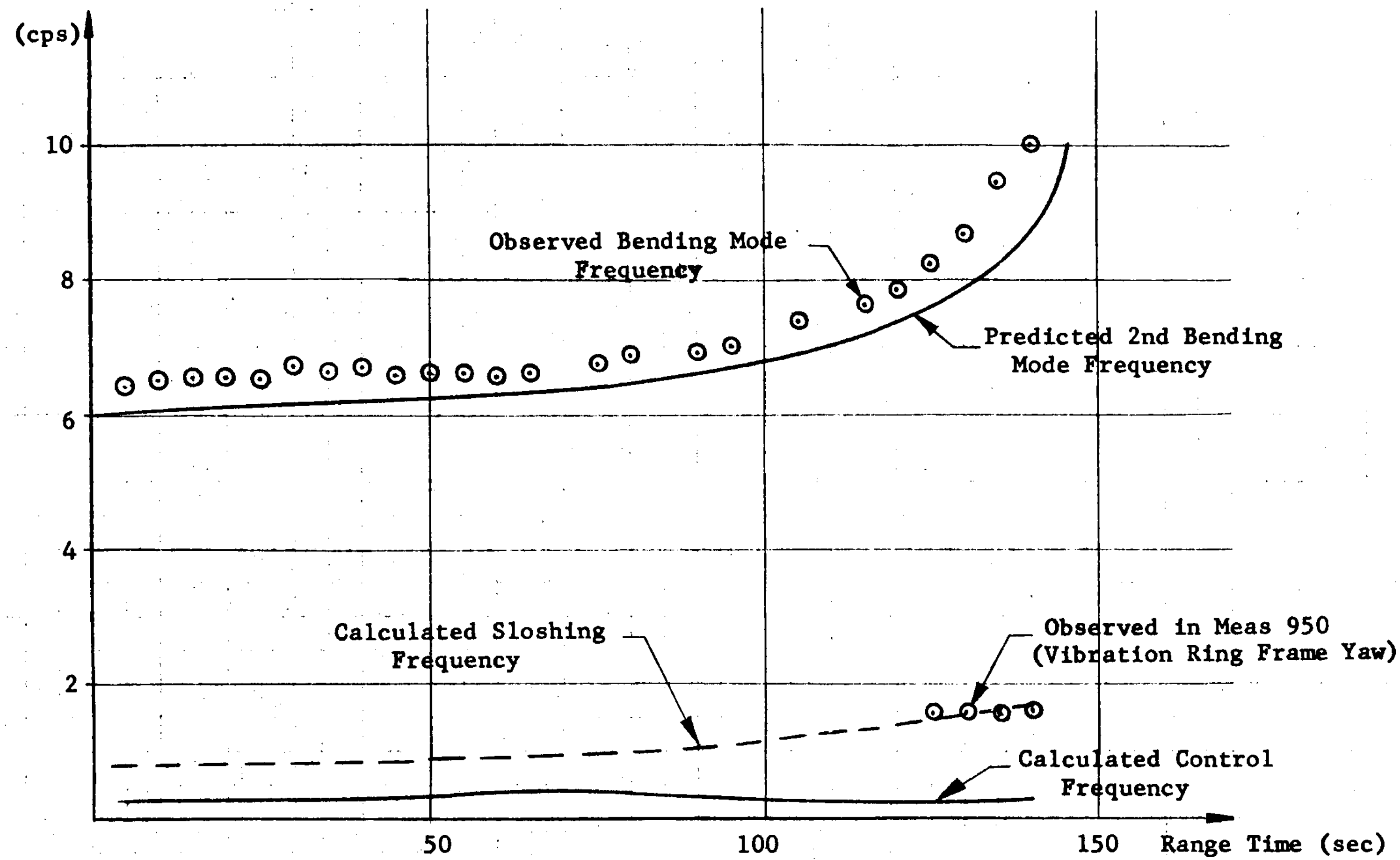


Fig. 24 MR-BD

VEHICLE OSCILLATIONS

It is noted that not only does MR-BD have a smaller second bending mode amplitude than on previous flights, but the actual telemetry traces of the angular velocity yaw and jet vane I deflection shown in Figure 25 indicates that the filtering network was effective in damping this mode. (For vehicle vibrations see paragraph 9, page 38.

8. (C) FREE FLIGHT MOTION

The LOX vent valve normally opens after cutoff thereby causing a forcing moment on the missile, essentially in the pitch plane. This moment tends to pitch the nose up. On MR-BD, based on the telemetered angular velocities, the LOX venting lasted until about 190 sec. The vehicle motion occurred essentially in the missile pitch plane, but there was also a lesser effect in yaw.

After the LOX venting had stopped, the residual angular velocity caused the vehicle to tumble end over end. The plane of this motion was inclined approximately 70 deg to the flight plane. The tumble rate was 5.4 deg/sec (or one revolution every 66.7 sec). The vehicle completed about four revolutions before being affected by the aerodynamic forces.

The telemetered body-fixed angular velocities are shown from cutoff to the loss of signal in Figure 26. The oscillatory component in the body-fixed pitch and yaw angular velocities prior to about 455 seconds is a result of the vehicle rolling.

As the vehicle re-entered, the aerodynamic forces again became significant and the motion was radically changed as the vehicle descended. Also, the air vanes started deflecting, apparently responding to control signals. The time scale in Figure 26 was expanded after 490 seconds to show better the higher frequency oscillations which occurred during this time.

By integrating the body-fixed angular velocities, it was estimated that the total angle of attack at 480 seconds was about 130 deg. The altitude at this time was about 56 km, with a dynamic pressure of about 100 kg/m^2. The angle of attack after this time is not known because of the erratic motions.

The telemetry signal was lost abruptly at 501.52 seconds and probably represents a structural breakup of the vehicle. At loss of telemetry signal, the dynamic pressure is estimated to be 3550 kg/m^2. Preliminary calculations by M-S&M-SD using an estimated angle of attack of 50 degrees indicate that the forces on the vehicle would be great enough to produce buckling. The most probable location of the

[redacted]

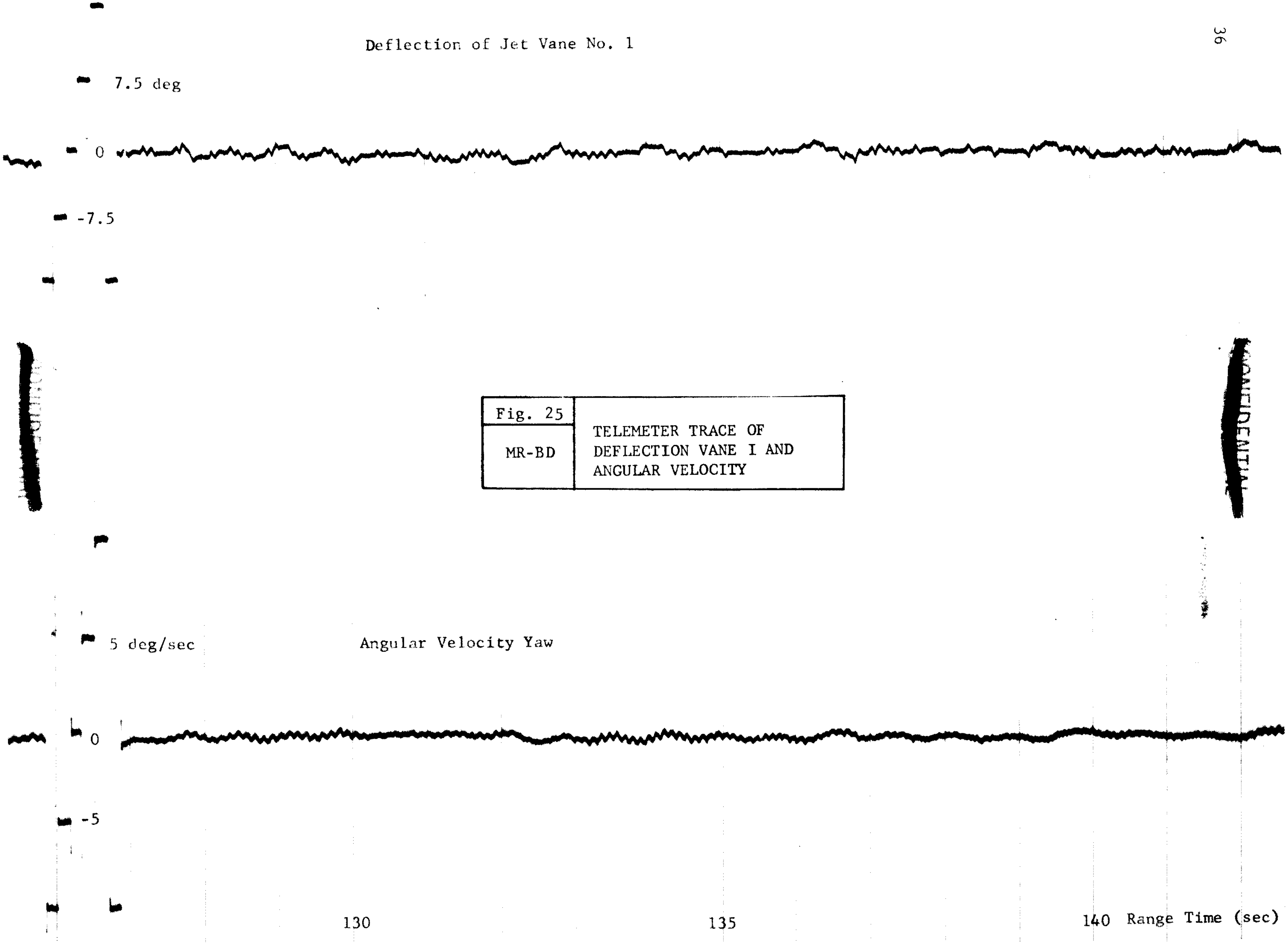


Fig. 25 MR-BD TELEMETER TRACE OF DEFLECTION VANE I AND ANGULAR VELOCITY

[redacted]

[redacted]

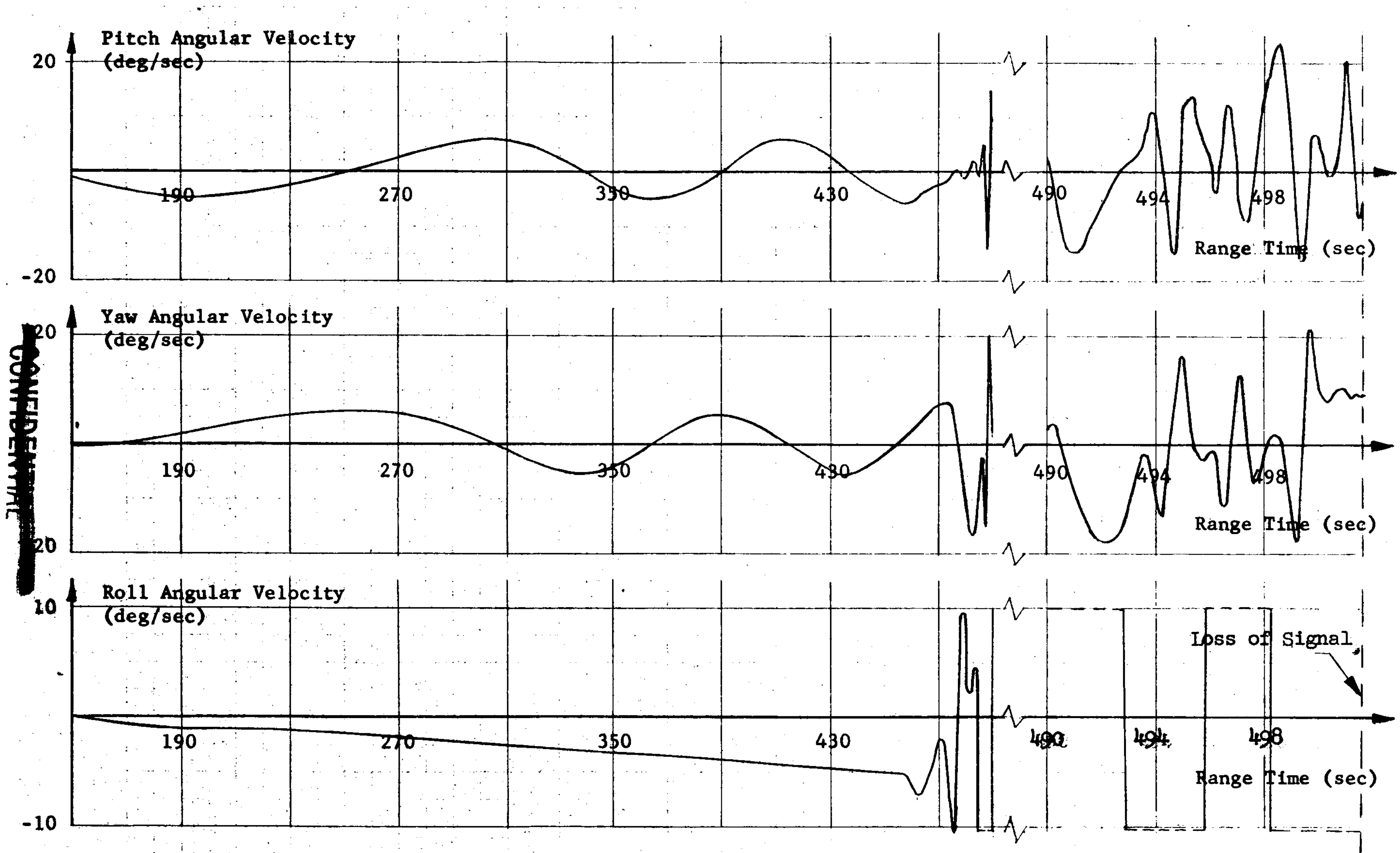


Fig. 26	TELEMETERED ANGULAR VELOCITIES (150 - 501.5 SEC)
MR-BD	

[redacted]

buckling is either the instrument compartment, fuel tank, or LOX tank. The bending moment distribution from the above conditions indicates the capsule-booster connection would still hold at this time. This is in agreement with telemetry which would have indicated a capsule separation if it had occurred prior to total loss of signal.

9. (U) VIBRATIONS

Three vibration transducers were installed in the aft unit of the MR-BD vehicle. Measurement 901 (range ± 12 g) was located on the adapter ring frame and was oriented to measure vibration in the pitch plane. Measurement 906, with a range of ± 8 g, was installed on the LEV-3 platform and was oriented to measure vibration in the longitudinal direction. A low frequency transducer, measurement 950, was installed on the forward ring frame of the instrument compartment. This transducer, designed for frequencies up to 16 cps, measured oscillations in the yaw plane (range ± 0.5 g).

The forward part of the aft unit was modified for this flight in an attempt to reduce the amplitude of oscillations at second bending mode frequencies. This modification consisted of four longitudinal stiffeners to the skin between station 1 and station 15 plus coating of the skin and instrument compartment forward bulkhead with a rubber base, lead impregnated, damping compound. The inside skin coating covered the portion of the aft unit from station 28 to station 15.

The general characteristics of the vibration measurements indicate that the increase in vibration level started later in this flight than in earlier flights with similar trajectories (see Table V). Since the higher amplitudes appeared later in flight, the length of time the high levels act on the instrument compartment is reduced. The amplitude of the vibrations, however, were only slightly reduced from those encountered on MR-2.

The measuring capabilities (± 12 g) of measurement 901, vibration capsule mounting ring, were again exceeded during portions of the flight. Since the vibration spectrum is mostly in the high frequency range this level is not considered critical.

10. (C) ABORT SYSTEM

The automatic abort system was flown "open loop" on MR-BD. This was the first flight test of the system since the removal of the roll rate sensor. The system performed as expected with no functional deviations. Table VI shows the abort sensors and their performance up to cutoff.

All components monitored by the abort system up to cutoff were within the expected range of operation and did not approach the abort limits.

The abort bus signal was activated at 149.41 sec (6.82 sec after cutoff). This signal was triggered by the pitch error abort sensor which was activated between 149.3 and 149.4 sec. The gyro pitch position minus program at this time had reached a value (-5.5 deg) within the operating range of the sensor (see page 28). As previously discussed, this pitch motion was caused by venting of LOX.

The telemetered command voltage (Figure 27) reached a low value of 59.4 volts. This was well above the abort level of 50 volts.

Operation of the combustion chamber pressure abort switches is shown on page 16. The telemetered chamber pressure and switch operation times do not agree with the specifications. Due to a unique occurrence in the commutated channels showing the operation of the two switches, the time at which the pressure passed the switch setting on pressure buildup could be determined accurately by assuming the two switches had the same setting. On chamber pressure decay the time at which the pressure passed the drop out setting is subject to the normal limitations of commutated channels (100 ms). It appears that the switches actuated on increasing pressure at 115 - 125 psia and dropped out on decreasing pressure somewhere between 315 and 255 psia. Specifications call for the switches to actuate on increasing pressure at 260 ± 15 psig with an actuation differential of 30 psi maximum. The fact that the switches actuated at an indicated pressure lower than the settings and dropped out at an indicated pressure higher than the settings shows that the difference between indicated and specified switch operation pressures is due primarily to the inability of the chamber pressure gauge to follow the rapidly changing transient pressures. The chamber pressure gauge used on the Mercury-Redstone has an accuracy of ± 5% and an estimated response time of 50 ms. This response time, applied to the pressure buildup and decay rates, shows that the pressure differences noted above can be expected in view of the instrumentation used.

(U) CONCLUSIONS

All missions assigned to MR-BD were accomplished. No system malfunctions occurred during the test.

The filter network added to the control system to reduce feedback in the second bending mode frequencies proved to be effective.

The combustion chamber pressure control system performance

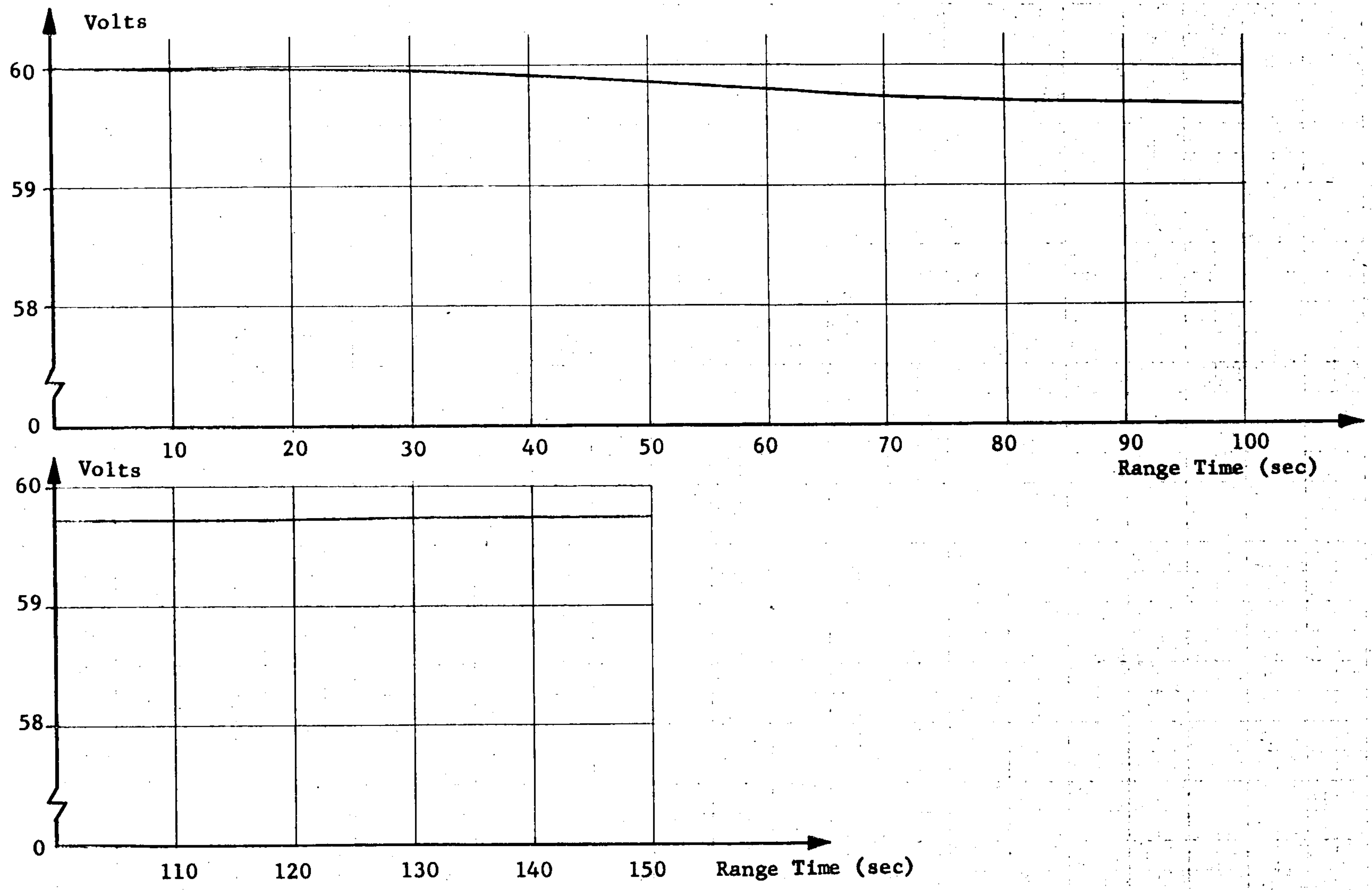


Fig. 27	BATTERY VOLTAGE COMMAND CONTROL (0 - 150 SEC)
MR-BD	

was excellent, showing that corrective action taken after the MR-2 flight was effective.

The abort system functioned correctly with no deviations being noted during the flight test.

A malfunction of the ΔP LOX topping system occurred during LOX topping operations. Surface winds of 16 - 20 knots caused LOX to slosh into the high level pressure sensing line causing LOX to overflow.

(U) CORRECTIVE ACTION

The following action has been taken to correct conditions noted during the launch of MR-BD:

To prevent a recurrence of the ΔP LOX topping system malfunction, a new ΔP, based on the most recent information available concerning metal shrinkage due to LOX, has been calculated and will be used to prevent overflow during LOX topping.

TABLE I

(C) Maximum Values

Parameter		Range Time (sec)	Value Actual	Value Predicted
Earth-fixed Velocity (m/s)	Ascent	143.31	2,002.8	1,983.5
	Descent	484.72	2,035.1	2,125.4
Longitudinal Acceleration (m/s^2)	Ascent	142.62	58.5	57.0
	Descent	*		129.4
Mach Number	Ascent	155.89	7.45	7.36
	Descent	491.14	6.17	7.36
Dynamic Pressure (kg/m^2)	Ascent	155.88	2,710	2,790
	Descent	*		89,000

* Occurred after loss of telemetry.

TABLE II

(C) Times of Events

Event	Range Time (sec)	Concluded from Measurement
Start Pressure Buildup	0.14	17, Chamber Pressure (C)
Abort Chamber Pressure Switch #2 Switch #1	Between 0.23 - 0.33 0.33 - 0.43	 729, Comb. Press. C.O. SW #2 (C) 728, Comb. Press. C.O. SW #1 (C)
Liftoff (Measuring Signal)	0.81	54, Liftoff (S)
Begin Tilt	25.1 ± .1	43, Tilting Program (S)
Tilt Arrest	79.1 ± .1	43, Tilting Program (S)
Resume Tilt	87.2 ± .1	43, Tilting Program (S)
Arm Cutoff to Capsule (Pulse)	130.31	227, Input to Flight Sequences (S)
Arm Cutoff to Capsule (Signal)	130.3 - 130.4	905, Arm Cutoff to Capsule (C)
Final Tilt Arrest	132.3 ± .1	43
Cutoff Signal	142.52	55, Cutoff (S)
Abort Chamber Pressure Switches #1 & #2 Functions	Between 142.57 & 142.67	728 729
Attitude Abort Sensed	Between 149.37 & 149.47	778, Attitude Error, Abort (C)
Abort Bus Hot*	149.41	680, Abort Bus Signal (S)
Loss of Telemetry	501.52	
Impact	656.45	

C - Commutated Channel
S - Straight Channel
* Due to Pitch Attitude Sensor

TABLE III

(C) MR-BD Vehicle Weights

Parameter	Predicted	Actual*	% Deviation from Predicted
Liftoff Weight (lb)	65,905	66,113 ± 200	+ 0.32 ± 0.30
Total Propellant Consumed (lb)	51,079	51,609 ± 239	+ 1.04 ± 0.47
Cutoff Weight (lb)	14,826	14,504 ± 439	- 2.17 ± 2.96
Fuel on Board at Liftoff (lb)	23,754	23,708 ± 71	- 0.19 ± 0.30
Fuel Consumed (lb)	22,415	22,418 ± 109	- 0.01 ± 0.49
Fuel Remaining at Cutoff (lb)	1,339	1,290 ± 180	-
Usable Fuel at Cutoff (lb)	1,250	1,201 ± 180	-
Residual Burning Time (sec)	7.95	7.59 ± 1.14	-
LOX on Board at Liftoff (lb)	29,035	29,022 ± 87	- 0.04 ± 0.30
LOX Consumed (lb)	27,795	28,318 ± 137	+ 1.88 ± 0.49
LOX Remaining at Cutoff (lb)	1,240	704 ± 224	-
Usable LOX at Cutoff (lb)	957	421 ± 224	-
Residual Burning Time (sec)	4.91	2.11 ± 1.12	-
H_2O_2 on Board at Liftoff (lb)	960	963 ± 3	+ 0.31 ± 0.31
H_2O_2 Consumed (lb)	871	873 ± 6	+ 0.23 ± 0.69
H_2O_2 Remaining at Cutoff (lb)	89	90 ± 9	-
Residual Burning Time (sec)	14.57	14.67 ± 1.46	-

* The actual values given above, with an estimate of the error in their determination, are obtained from the ballistic evaluation (see page These values do not deviate from the corresponding values determined from the measured parameters by more than 1.3% in any case except the H_2O_2 flow rate which deviates by 1.8%.

TABLE IV

(C) MR-BD Power Plant Parameters

Parameter	Predicted	Actual*	% Deviation from Predicted
Alcohol Flow Rate (lb/sec)	157.30	158.20 ± 0.77	+ 0.57 ± 0.49
LOX Flow Rate (lb/sec)	194.80	199.58 ± 0.97	+ 2.45 ± 0.50
H_2O_2 Flow Rate (lb/sec)	6.11	**6.16 ± 0.04	+ 0.82 ± 0.66
Total Flow Rate (lb/sec)	358.45	364.19 ± 1.69	+ 1.60 ± 0.47
Mixture Ratio	1.2384	1.2616***	+ 1.87
Thrust Chamber Pressure (psia)	317.5	319.14 ± 1.18	+ 0.52 ± 0.37
Throat Area (in^2)	183.6	183.99	+ 0.21
Sea Level Thrust Coefficient	1.3354	1.3389 ± 0.0006	+ 0.26 ± 0.05
Sea Level Thrust (lb)	78,000	78,780 ± 326	+ 1.00 ± 0.42
Sea Level Specific Impulse (sec)	217.63	216.32 ± 0.67	- 0.60 ± 0.31
Area Ratio	3.61:1	3.55:1	- 1.66

* The actual values given above, with an estimate of the error in their determination, are obtained from the ballistic evaluation (see page 14). These values do not deviate from the corresponding values determined from the measured parameters by more than 1.3% in any case except the H_2O_2 flow rate which deviates by 1.8%.

** Adjusted by 0.1 lb/sec for each 3 psia that the chamber pressure deviates from predicted.

*** Measured mixture ratio used.

TABLE V

Vibration Time History for Mercury-Redstone Flights

Measurement 901, Vibration Capsule Mounting Ring - Lateral

Flight Number	Amplitude Increase Starts (sec)	Maximum Amplitude Reached (sec)	Return to Low Level (sec)
MR-1A	28	65	135
MR-2	24	68	130
MR-BD	37	70	130

Measurement 906, Vibration LEV-3 Base Plate

Flight Number	Amplitude Increase Starts (sec)	Maximum Amplitude Reached (sec)	Return to Low Level (sec)
MR-1A*	40	70	120
MR-2	38	65	115
MR-BD	50	69	115

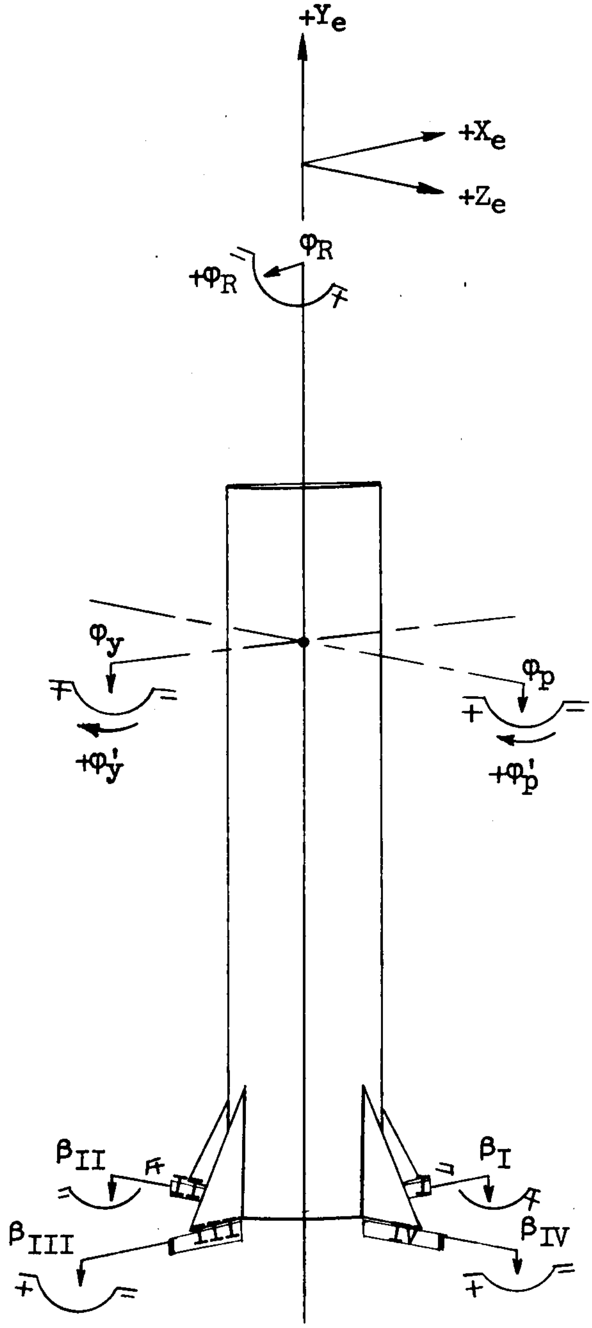
* Measurement 903 (Vibration Rate Switch) used for comparison since 906 was not flown on MR-1A.

TABLE VI

(C) MR-BD Abort Sensor Performance Before Cutoff

Sensor	Abort Limits	Tolerance	Measured Extreme Value	% of Abort Limit
D. C. Command Voltage	Drop to 50 Volts*	± 2 volts	59.4	6
Attitude Error				
Pitch	± 5 deg	+ 1.0 deg - 0 deg	0.82 deg	16
Yaw	± 5 deg	+ 1.0 deg - 0 deg	1.71 deg	34
Roll	± 10 deg	+ 2.0 deg - 0 deg	1.45 deg	29
Rate Switch				
Pitch	± 5 deg/sec	+ 0.3 deg/sec - 0 deg/sec	1.75 deg/sec	35
Yaw	± 5 deg/sec	+ 0.3 deg/sec - 0 deg/sec	0.69 deg/sec	14
Combustion Chamber	Drop to 210 psig**	± 15 psig	315 psia	2.3

* Nominal Voltage 60 V
** Nominal Pressure 317.5 psia



MERCURY-REDSTONE BOOSTER SIGN CONVENTION

Diagram 1

(U) REFERENCES

1. Memorandum from M-AERO-P, Project Mercury Redstone: Trajectory Data for MR-BD, March 20, 1961, Confidential.

2. Report No. DSD-TM-1-60, Predicted Propulsion System Performance for Mercury-Redstone (MR-1), Carl Gibson, January 28, 1960, Confidential.

3. TWX No. CCMTA-62, Preliminary Weight Data MR-BD, March 27, 1961, Confidential

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